2. SITE CHARACTERISTICS

2.1 Introduction

2.1.1 Site Location and Description

2.1.1.1 Technical Information in the Application

In Section 2.1.1.1 of the site safety analysis report (SSAR), the applicant presented information concerning the site location and site area that would affect the design of structures, systems, and components (SSCs) important to safety of a nuclear power plant or plants falling within the applicant's plant parameter envelope (PPE) that might be constructed on the proposed early site permit (ESP) site. The applicant did not provide latitude and longitude or Universal Transverse Mercator coordinates for new units in the proposed ESP site. However, the North Anna Units 1 and 2 Updated Final Safety Analysis Report (UFSAR) for the existing North Anna Power Station (NAPS) does include them. The proposed ESP site is located within the existing NAPS site.

The applicant provided the following information on site location and site area:

- the site boundary for new units in the proposed ESP site with respect to the existing units
- the site layout for new units in the proposed ESP site with respect to the current and future developments
- the site location with respect to political subdivisions and prominent natural and manmade features of the area within the 6-mile (mi) low-population zone (LPZ) and 50-mile population zone
- the topography surrounding the proposed ESP site
- the distance from the proposed ESP site to the nearest exclusion area boundary (EAB), including the direction and distance
- the potential radioactive material release points and their locations for the proposed new units
- the distance of the proposed site from regional U.S. and State highways
- the confirmation that no physical characteristics unique to the proposed ESP site were identified that could pose a significant impediment to the development of emergency plans

2.1.1.2 Regulatory Evaluation

Sections 1.8 and 2.1.1 of the SSAR identify the applicable U.S. Nuclear Regulatory Commission (NRC) regulations and guidance regarding site location and description as defined in Title 10, Section 52.17, "Contents of Applications," of the *Code of Federal Regulations* (10 CFR 52.17); 10 CFR Part 100, "Reactor Site Criteria"; 10 CFR 50.34(a)(1); and NRC Review Standard (RS)-002, "Processing Applications for Early Site Permits," issued May 2004. The staff reviewed this portion of the application for conformance with the applicable regulations, and considered the corresponding regulatory guidance, as identified above.

The staff considered the following regulatory requirements in reviewing the site location and site area:

- 10 CFR Part 100, insofar as it requires consideration of factors relating to the size and location of sites
- 10 CFR 52.17, insofar as it requires the applicant's submission of information needed to evaluate factors involving the characteristics of the site environs

According to Section 2.1.1 of RS-002, an applicant has submitted adequate information if it satisfies the following criteria:

- The site location, including the exclusion area and the proposed location of a nuclear power plant or plants of specified type falling within a PPE that might be constructed on the proposed site, is described in sufficient detail to determine that the requirements of 10 CFR Part 100 and 10 CFR 52.17 are met, as discussed in Sections 2.1.2 and 2.1.3 and Chapter 15 of this safety evaluation report (SER).
- Highways, railroads, and waterways which traverse the exclusion area are sufficiently distant from planned or likely locations of structures of a nuclear power plant or plants of specified type falling within a PPE that might be constructed on the proposed site so that routine use of these routes is not likely to interfere with normal plant operation.

2.1.1.3 Technical Evaluation

The proposed ESP site is located within the existing NAPS site. The ESP site boundary, as shown in Figure 2.1-1, "Site Boundary," of the SSAR, is the same as the site boundary for the existing NAPS units.

The staff has verified the following coordinates of the existing NAPS units provided in the North Anna UFSAR:

	Latitude	Longitude	Universal Transverse Mercator
Unit 1	38°3'36"N	77°47'23"W	4,215,990 mN—255,240 mN—zone 18S
Unit 2	38°3'38"N	77°47'26"W	4,215,960 mN—255,170 mN—zone 18S

The staff will review the exact coordinates of the new units at the time of a combined license (COL) or construction permit (CP) application when the applicant selects new units in the proposed ESP site. This is **COL Action Item 2.1-1.**

The applicant has defined the EAB envelope at a radius of 5000 feet (ft) from the now abandoned Unit 3 containment and the LPZ at a radius of 6 miles from the existing Unit 1 containment building. The applicant established the EAB and the LPZ to ensure that the radiological consequence evaluation factors identified in 10 CFR 50.34(a)(1) and the siting evaluation factors in Subpart B, "Evaluation Factors for Stationary Power Reactor Site Applications on or After January 10, 1997," of 10 CFR Part 100 are met. No persons live within the EAB.

NAPS is located in the northeastern portion of Virginia in Louisa County. Louisa County includes two incorporated towns, Louisa and Mineral. The proposed ESP site is on a peninsula on the southern shore of Lake Anna at the end of State Route 700. Lake Anna was created to serve the needs of NAPS. It is about 17 miles long and has 272 miles of irregular shoreline with various contour and scenic views. The proposed ESP site lies along the lake shoreline. The NAPS property comprises 1803 acres (ac), of which about 760 ac are covered by water. Virginia Electric and Power Company (Virginia Power) and Old Dominion Electric Cooperative (ODEC) own the NAPS site, which includes the existing two nuclear power units and the proposed ESP site, as tenants in common (see Section 2.1.2 of this SER).

The largest community within 10 miles of the proposed ESP site is the town of Mineral with a population of 424, according to the 2000 census. It is situated about 6 miles west-southwest of the proposed ESP site. Regionally, as shown in Figure 2.1-3, "Fifty-Mile Surrounding Area," of the SSAR, the proposed site is approximately 40 miles north-northwest of Richmond, Virginia; 36 miles east of Charlottesville, Virginia; 22 miles southwest of Fredericksburg, Virginia; and 70 miles southwest of Washington, D.C. Highways U.S. 1 and I-95 pass within 15 and 16 miles, respectively, east of the proposed site. No highways, railroads, or waterways traverse the proposed ESP exclusion area site boundary.

The staff has verified that the exclusion area distance is consistent with the distance the applicant used in its radiological consequence analyses described in Chapter 15, "Accident Analyses," of the SSAR. The applicant stated that, consistent with the licenses for the existing units, the gaseous effluent release limits for the proposed units would apply at or beyond the proposed ESP EAB; the liquid effluent release limits for the new units would apply at the end of the discharge canal, which is designated as the release point to unrestricted areas. The staff finds that these release points are acceptable for determining the radiation exposures to the public to meet the criterion "as low as reasonably achievable," cited in Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low as is Reasonably Achievable,' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."

For the reasons set forth in Section 13.3 of this SER, the staff further finds that no physical characteristics unique to the proposed ESP site have been identified that could pose a significant impediment to the development of emergency plans.

2.1.1.4 Conclusions

As set forth above, the applicant has provided and substantiated information concerning the site location and site area that would affect the design of SSCs important to safety of a nuclear power plant or plants of specified type falling within the applicant's PPE that might be constructed on the proposed ESP site. The staff has reviewed the applicant's information as described above and concludes that it is sufficient for the staff to evaluate compliance with the siting evaluation factors in 10 CFR Part 100 and 10 CFR 52.17, as well as the radiological consequence evaluation factors in 10 CFR 50.34(a)(1). The staff further concludes that the applicant provided information concerning the site location and site area in sufficient detail to allow the staff to evaluate, as documented in Sections 2.1.2 and 2.1.3 and Chapter 15 of this SER, whether the applicant has met the relevant requirements of 10 CFR Part 100 and 10 CFR 52.17.

2.1.2 Exclusion Area Authority and Control

2.1.2.1 Technical Information in the Application

In SSAR Section 2.1.2, the applicant presented information concerning its plan to obtain legal authority to determine all activities within the designated exclusion area, if it decides to proceed with the development of new reactor units at the proposed ESP site. In Revision 3 of the SSAR, the applicant stated the following:

> If Dominion decides to proceed with the development of new units, it would enter into and obtain appropriate regulatory approvals to purchase or lease the ESP site from Virginia Power and ODEC. The agreement or conveyance documents would provide for the mutual use of the NAPS site as a single exclusion area. As part of this agreement, each party would agree to immediately notify the other in the event of an emergency and to abide by the reasonable requests of the party declaring an emergency to exclude non-plant personnel and property from the exclusion area. The parties would also agree to work cooperatively to control third party activity that might otherwise present an unacceptable hazard to nuclear operations. Because the appropriate regulatory approvals of the conveyance and agreement (pursuant to Virginia Code, 56-77 and 56-580) would be a prerequisite to Dominion's development of the new units, such arrangements would be in place before issuance of a COL for the new units.

In Request for Additional Information (RAI) 2.1.2-1, the staff asked the applicant for additional information regarding its approach to obtaining appropriate regulatory approvals to purchase or lease the ESP site. In its response, the applicant stated the following:

> Virginia State Corporation and possibly North Carolina Utilities Commission approval [other than NRC] would be required [to purchase or lease the proposed ESP site]. The current NAPS exclusion area boundary (EAB) would continue to be the EAB for the existing units and any new units. This single exclusion area includes property that is not part of the ESP site. The use of the current exclusion area for the new units would be established by agreement between Dominion Nuclear North Anna and other NAPS owners. Dominion has not determined a specified term for any lease. However, any lease would provide that (1) the term of the lease would not expire until after termination of all NRC licenses for any facilities on the leased property, and (2) the lease may not be canceled or terminated, prior to the termination of all NRC licensees for any

> facilities on the leased property, except with prior written consent of the NRC (e.g., consent in connection with the transfer of licenses under 10 CFR 50.80).

In RAI 2.1.2-2, the staff asked for the application for additional information on how an agreement or conveyance document (e.g., a lease or deed) would provide for the use of NAPS as a single exclusion area, in the event that additional reactors are constructed on the site. In its response, in a letter to the NRC dated August 10, 2004, the applicant stated the following:

> Any lease or deed would provide mutual use of the existing site and the leased premises as a single exclusion area and single restricted area for all nuclear units at the North Anna site. Each party would agree to immediately notify the other in the event of an emergency and to abide by the reasonable request of the party declaring the emergency condition to exclude non-plant personnel and property from the exclusion area. The parties would agree to work cooperatively to control third party activity within the exclusion area and prevent any such activity that might otherwise present an unacceptable hazard to nuclear operations. This approach is consistent with the single exclusion area established by agreement for the Indian Point units (when Units 1 and 2 were owned by the Consolidated Edison Company and Unit 3 was owned by the Power Authority of the State of New York) and for the Nine Mile Point and Fitzpatrick plants.

2.1.2.2 Regulatory Evaluation

In SSAR Sections 1.8 and 2.1.2, the applicant identified the applicable NRC regulations and regulatory guidance regarding exclusion area authority and control related to Subpart A, "Early Site Permits," of 10 CFR Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants," 10 CFR Part 100, and RS-002. The staff finds that the applicant correctly identified the applicable regulations and guidance. The staff considered 10 CFR 100.21(a) and 10 CFR 100.3, "Definitions," in reviewing the applicant's legal authority to determine all activities within the designated exclusion area. Pursuant to 10 CFR 100.21(a), every site must have an exclusion area, defined in 10 CFR 100.3 as the following:

> That area surrounding the reactor, in which the reactor licensee has the authority to determine all activities including exclusion or removal of personnel and property from the area. This area may be traversed by a highway, railroad or waterway, provided these are not so close to the facility as to interfere with normal operations of the facility and provided appropriate and effective arrangements are made to control traffic on the highway, railroad, or waterway, in case of emergency, to protect the public health and safety... Activities unrelated to operation of the reactor may be permitted in an exclusion area under appropriate limitations, provided that no significant hazards to the public health and safety will result.

As stated in Section 2.1.2 of RS-002, the applicant must demonstrate, before issuance of an ESP, that it has an exclusion area and an LPZ, as defined in 10 CFR 100.3 and in accordance with the requirements of 10 CFR Part 100. Furthermore, the applicant must show that it has the authority within the exclusion area, as required by 10 CFR 100.3, or it must provide reasonable assurance that it will have such authority before start of construction of a reactor or reactors that might be located on the proposed ESP site.

2.1.2.3 Technical Evaluation

As set forth in the application and in Section 2.1.2.1 of this SER, the exclusion area for the North Anna ESP site is identical to the exclusion area for the existing reactors at the site, North Anna Units 1 and 2. Further, the current owners of the ESP site, Virginia Power and ODEC, have the requisite control over the exclusion area, and such control is vested in Virginia Power. The applicant has stated that it intends to reach appropriate legal terms with the current owners of the ESP site to obtain the requisite control over the exclusion area. The applicant would enter into such an agreement with the current site owners at such time as the applicant elects to construct a nuclear power plant on the site.

The applicant has not attempted to demonstrate that it currently has the authority to determine all activities, including exclusion or removal of personnel and property from the area, as required by 10 CFR 100.3. To meet the exclusion area control requirements of 10 CFR 100.21(a) and 10 CFR 100.3, the applicant does not need to demonstrate total control of the property before issuance of the ESP. In the draft safety evaluation report (DSER), the NRC staff stated that the applicant must provide reasonable assurance that it can acquire the required control (i.e., that it has the legal right to obtain control of the exclusion area). The staff had not then obtained information sufficient to enable it to determine whether the applicant had such a legal right. Accordingly, the NRC staff identified DSER Open Item 2.1-1, which stated that the applicant should demonstrate that it has the legal right to control the exclusion area, or has an irrevocable right to obtain such control.

In its response to the open item, the applicant indicated as follows: In accordance with Virginia Code, §56-580 D, the ESP holder would be required to obtain the approval of the Virginia State Corporation Commission (SCC) to construct and operate any new unit at the North Anna ESP site, should it decide to do so. In such an event, SCC approval of any agreement between the CP or COL applicant and the current owners of the site providing for construction and operation of a new unit would be required pursuant to Virginia Code, §56-77. The same statute would require SCC approval of any agreement among these entities providing for joint control of the exclusion area. Other State approvals might also be required.

Based on the above information, the staff has determined that State approval would be required for the agreements described above, and no new nuclear power plant could be built in the absence of these approvals. Since the ESP holder would need to obtain the current owners' agreement to construct and operate any new nuclear power plant on the North Anna ESP site in order to seek State approval of such construction and operation, there does not appear to be any reason why the ESP holder could not obtain control of the exclusion area in a similar manner. Accordingly, for purposes of an ESP, there is reasonable assurance that the current owners would (as a corollary to any agreement for construction and operation) also agree to joint control of the exclusion area with the ESP holder, as proposed by the applicant, and seek the required State approvals of such an agreement or agreements. In addition, there does not appear to be any impediment to joint control of the exclusion area in the event State approval of such an arrangement is granted.

The State approvals described above would not be granted until sought upon a decision to seek a CP or COL, and do not currently vest a legal right in the applicant to obtain control of the exclusion area. Accordingly, the NRC staff proposes to include a condition in any ESP that might be issued to govern exclusion area control as **Permit Condition 1.** This permit condition would require that approvals called for by State law for, among other matters, agreements providing for shared control of the North Anna ESP exclusion area, be obtained and the agreements executed before construction of a nuclear power plant begins under a construction permit or COL referencing the ESP. Such a permit condition provides reasonable assurance that an ESP provides for control of the exclusion area. The condition requires that these arrangements be obtained and executed before the granting of an application referencing the ESP. Therefore, DSER Open Item 2.1-1 is closed.

Should the NRC grant the ESP and the ESP holder decide to perform the activities authorized by 10 CFR 52.25, "Extent of Activities Permitted," the ESP holder must obtain the authority to undertake those activities on the ESP site. In obtaining such a right, the ESP holder must also obtain the corresponding right to implement the site redress plan described in the staff's final environmental impact statement in the event that no plant is built on the ESP site. The staff proposes to include a condition in any ESP that might be issued requiring that the ESP holder obtain the right to implement the site redress plan before initially any activities authorized by 10 CFR 52.25, as **Permit Condition 2.**

The North Anna exclusion area extends into Lake Anna and the waste heat treatment facility (WHTF). Should the NRC grant the ESP and the ESP holder decide to apply for a COL (or for a CP and operating license (OL)), the ESP holder, COL or CP applicant must make arrangements with the appropriate Federal, State, or local agencies to provide for control of the portions of Lake Anna and the WHTF that are within the exclusion area. These agencies, together with COL or CP applicant, must have authority over these bodies of water sufficient to allow for the exclusion and ready removal, in an emergency, of any persons present on them. This is **COL Action Item 2.1-2.** No State or county roads, railways, or waterways traverse the North Anna ESP exclusion area.

2.1.2.4 Conclusions

As set forth above, the applicant has provided and substantiated information concerning its plan to obtain legal authority to determine all activities within the designated exclusion area. The staff has reviewed the applicant's information and concludes that it is sufficient to evaluate compliance with the exclusion area control requirements of 10 CFR 100.21(a) and 10 CFR 100.3.

The applicant has appropriately described the exclusion area and the methods by which access and occupancy of the exclusion area will be controlled during normal operation and in the event of an emergency situation.

Based on the foregoing, the staff concludes that the applicant's exclusion area is acceptable and meets the requirements of 10 CFR Part 100, subject to the limitations and conditions identified in this SER. Such permit conditions provide reasonable assurance that an ESP provides for control of the exclusion area. Further, the ESP holder must demonstrate that it will have authority to perform the activities authorized by 10 CFR 52.25, should it choose to do so, and the corresponding right to implement the site redress plan, as described in the discussion of Permit Conditions 1 and 2.

2.1.3 Population Distribution

2.1.3.1 Technical Information in the Application

In SSAR Section 2.1.3, the applicant estimated and provided the population distribution surrounding the proposed ESP site, up to a 50-mile radius, based on the most recent U.S. census. In this section, the applicant also provided the population densities, the resident population distribution within the LPZ, the nearest population center, and population densities up to a 50-mile radius from the proposed ESP site.

The population distribution provided by the applicant encompasses nine concentric rings at various distances out to 50 miles from the proposed ESP site and 16 directional sectors. The applicant also estimated and provided transient population data out to 50 miles based on recreational use of Lake Anna, Lake Anna State Park, two commercial campgrounds, the WHTF, and Paramount's King's Dominion Amusement Park.

In RAI 2.1.3-1, the staff asked the applicant to project population estimates, including weighted transient populations, up to 2065 (the projected year for the end of plant life). In its response, the applicant reestimated and provided resident and weighted transient populations up to 2065, thereby revising its original estimate of resident and weighted transient populations up to 2040. The applicant incorporated this response into the SSAR.

In the revised Figure 2.1-14 of the SSAR, the applicant provided the cumulative population in 2000 and the projected cumulative population in 2065, as functions of the 10-mile to 50-mile radial distance from the proposed ESP site, as well as the population density curves spanning the same radial distances. The population density curves also included 500-persons-per-square-mile lines and 1000-persons-per-square-mile lines as a function of distance up to 50 miles from the site.

The applicant established the LPZ to ensure that the radiological consequences of design-basis reactor accidents at the LPZ meet the dose consequence evaluation factors set forth in 10 CFR 50.34(a)(1). The applicant described the LPZ in Section 2.1.3.4 of the SSAR. The LPZ is defined in 10 CFR 100.3 as "the area immediately surrounding the exclusion area which contains residents, the total number and density of which are such that there is a reasonable probability that appropriate measures could be taken in their behalf in the event of a serious accident." The LPZ for the ESP site is the same as the LPZ for the existing North Anna units; it consists of a circle with a radius of 6 miles centered on the North Anna Unit 1 containment building. The applicant provided a map (Figure 2.1-2) of the LPZ and figures showing the current and projected population data for the LPZ, including transient persons.

The applicant described the population center in Section 2.1.3.5 of the SSAR. The population center is defined in 10 CFR 100.3 as "a densely populated center containing more than about 25,000 residents." The applicant stated that the nearest population center with a population greater than 25,000 people which is likely to exist over the lifetime of the proposed ESP site, is the city of Charlottesville, with a population of 45,049. The closest point of Charlottesville is 36 miles west of the ESP site. The next closest population center is Fredericksburg, which is 22 miles northeast of the proposed ESP site. Fredericksburg has a projected population of about 20,330 in 2065.

In RAI 2.1.3-2, the staff asked the applicant to describe appropriate protective measures that could be taken on behalf of the populace in the LPZ in the event of a radiological emergency. In its response, the applicant stated that, in the event of a radiological emergency, the plant staff would notify the Commonwealth of Virginia and local authorities. The plant staff would formulate protective action recommendations, as appropriate, and provide them to the Virginia Emergency Operations Center. The Commonwealth of Virginia would make a protective action decision and notify the affected populace.

2.1.3.2 Regulatory Evaluation

In SSAR Sections 1.8 and 2.1.3, the applicant identified the applicable NRC regulations and regulatory guidance regarding population distribution, as described in 10 CFR 52.17; 10 CFR Part 100; Regulatory Guide (RG) 4.7, Revision 2, "General Site Suitability Criteria for Nuclear Power Stations," issued April 1998; and RS-002. The staff finds that the applicant correctly identified the applicable regulations and guidance.

The staff considered the following regulatory requirements in its review of this section of the SSAR:

- 10 CFR 52.17, insofar as it requires each applicant to provide a description and safety assessment of the site, and insofar as it requires that site characteristics comply with 10 CFR Part 100

- 10 CFR Part 100, insofar as it establishes requirements with respect to population density

In particular, the staff considered the population density and use characteristics of the site environs, including the exclusion area, LPZ, and population center distance. The regulations in 10 CFR Part 100 provide definitions and other requirements for determining an exclusion area, LPZ, and population center distance.

As stated in Section 2.1.3 of RS-002, the applicable requirements of 10 CFR 52.17 and 10 CFR Part 100 are deemed to have been met if the population density and use characteristics of the site meet the following criteria:

- Either there are no residents in the exclusion area, or if residents do exist, they are subject to ready removal, in case of necessity.

- The specified LPZ is acceptable if it is determined that appropriate protective measures could be taken on behalf of the enclosed populace in the event of a serious accident.

- The population center distance is at least one and one-third times the distance from the reactor to the outer boundary of the LPZ. The population center distance is defined in

10 CFR 100.3 as the distance from the reactor to the nearest boundary of a densely populated center containing more than about 25,000 residents.

- The population center distance is acceptable if there are no likely concentrations of greater than 25,000 people over the lifetime (plus the term of the ESP) of a nuclear power plant or plants of specified type or falling within a PPE that might be constructed on the proposed site closer than the distance designated by the applicant as the population center distance. The boundary of the population center shall be determined upon considerations of population distribution. Political boundaries are not controlling.

- The population data supplied by the applicant in the safety assessment are acceptable if (1) they contain population data for the latest census, projected year(s) of startup of a nuclear power plant or plants of specified type (or falling within a PPE) that might be constructed on the proposed site (such date(s) reflecting the term of the ESP) and a projected year(s) of end of plant life, all in the geographical format given in Section 2.1.3 of RG 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants—LWR Edition," Revision 3, issued November 1978, (2) they describe the methodology and sources used to obtain the population data, including the projections, (3) they include information on transient populations in the site vicinity, and (4) the population data in the site vicinity, including projections, are verified to be reasonable by other means, such as U.S. Census Bureau publications, publications from State and local governments, and other independent projections.

- If the population density at the ESP stage exceeds the guidelines given in RG 4.7, Revision 2, special attention to the consideration of alternative sites with lower population densities is necessary. A site that exceeds the population density guidelines of Regulatory Position C.4 of RG 4.7, Revision 2, can nevertheless be selected and approved if, on balance, it offers advantages compared with available alternative sites when all of the environmental, safety, and economic aspects of the proposed and alternative sites are considered.

2.1.3.3 Technical Evaluation

The staff reviewed the data on the population in the site environs, as presented in the applicant's SSAR, to determine whether the exclusion area, LPZ, and population center distance for the proposed ESP site comply with the requirements of 10 CFR Part 100 and the acceptance criteria in Section 2.1.3.2 of this SER. The staff also evaluated whether, consistent with Regulatory Position C.4 of RG 4.7, Revision 2, the applicant should consider alternate sites with lower population densities. The staff also reviewed whether appropriate protective measures could be taken on behalf of the enclosed populace within the emergency planning zone (EPZ), which encompasses the LPZ, in the event of a serious accident.

The staff compared and verified the applicant's population data against U.S. Census Bureau Internet data. As documented in Section 13.3 of this SER, the staff reviewed the projected population data provided by the applicant. The information reviewed by the staff included the weighted transient populations for 2010, 2020, 2030, 2040, 2050, 2060, and 2065. If the NRC were to approve and issue the ESP in 2006 and a COL application submitted near the end of the ESP term, with a projected startup of new units in about 2025 and an operational period of 40 years for the new units, the projected year for end of plant life is about 2065. Accordingly, the staff finds that the applicant's projected population data cover an appropriate number of years and are reasonable.

The staff reviewed the transient population data provided by the applicant. The transient population up to a 50-mile radius is based on recreational use of Lake Anna, Lake Anna State Park, two commercial campgrounds, the WHTF, and Paramount's King's Dominion Amusement Park. The applicant stated that recreational use of Lake Anna, including Lake Anna State Park, is the greatest contributor to transient population in the area. The applicant collected information concerning transient population of the area from a number of contributing factors, including the number of boat ramps, wet slips, campsites, and picnic areas. Based on this information, the staff finds that the applicant's estimate of the transient population is reasonable.

The staff notes that no member of the public lives within the exclusion area.

The applicant evaluated representative design-basis accidents in Chapter 15 of the SSAR, and the staff independently verified the applicant's evaluation in Chapter 15 of this SER to demonstrate that the radiological consequences of design-basis reactor accidents at the proposed LPZ would be within the dose consequence evaluation factors set forth in 10 CFR 50.34(a)(1).

The distances to Charlottesville and Fredericksburg, the nearest population centers, are well in excess of the minimum population center distance of 7.8 miles (one and one-third times the distance of 6 miles from the reactor to the outer boundary of the LPZ). In addition, no population centers are closer than the population center distance specified by the applicant.

Therefore, the staff concludes that the proposed ESP site meets the population center distance requirement, as defined in 10 CFR Part 100. The staff has determined that no realistic likelihood exists that there will be a population center with 25,000 people within the 7.8-mile minimum population center distance during the lifetime of any new units that might be constructed on the site. This conclusion is based on projected cumulative resident and transient population within 10 miles of the site during the lifetime of any new units to 2065.

The staff evaluated the site against the criterion in Regulatory Position C.4 of RG 4.7, Revision 2, regarding whether it is necessary to give special attention to the consideration of alternative sites with lower population densities. The criterion is whether the population densities in the vicinity of the proposed site, including weighted transient population, projected at the time of initial site approval and within about 5 years thereafter, would exceed 500 persons per square mile averaged over any radial distance out to 20 miles (cumulative population at a distance divided by the area at that distance). The staff has determined that such population densities for the proposed site would be well below this criterion. Therefore, the staff concludes that the site conforms to Regulatory Position C.4 in RG 4.7, Revision 2. Assuming construction of a new nuclear reactor or reactors at the proposed site beginning near the end of the term of the ESP, and based on its review of the applicant's population density data and projections, the staff finds that the site also meets the guidance of RS-002 regarding population densities over the lifetime of facilities that might be constructed at the site, in that the population density over that period would be expected to remain below 500 persons per square mile averaged out to 20 miles from the site.

The staff reviewed information provided by the applicant regarding its ability to take appropriate protective measures on behalf of the populace in the LPZ in the event of a serious accident. In its response to RAI 2.1.3-2, the applicant stated that, in the event of a radiological emergency, the plant staff would notify the Commonwealth of Virginia and local authorities. The plant staff would formulate protective action recommendations, as appropriate, and provide them to the Virginia Emergency Operations Center. The Commonwealth of Virginia would make a protective action decision and notify the affected populace.

The staff finds that the applicant's response is satisfactory because it is consistent with emergency planning for the 10-mile plume exposure EPZ. The LPZ is located entirely within the 10-mile EPZ. Comprehensive emergency planning for the protection of all persons within the 10-mile EPZ, as addressed in Section 13.3 of this SER, would include those persons within the LPZ. Based on the information the applicant presented on this subject, and on the staff's conclusions discussed in Section 13.3 of this SER, the staff concludes that appropriate protective measures could be taken on behalf of the enclosed populace within the LPZ in the event of a serious accident.

2.1.3.4 Conclusions

As set forth above, the applicant has provided an acceptable description of current and projected population densities in and around the site. These densities projected at the time of initial plant operation (if one were to be constructed on the site) and within about 5 years thereafter are within the guidelines of Regulatory Position C.4 of RG 4.7, Revision 2. The applicant has properly specified the LPZ and population center distance. The staff finds that the proposed LPZ and population center distance meet the definitions in 10 CFR 100.3. Therefore, the staff concludes that the applicant's population data and population distribution are acceptable and meet the requirements of 10 CFR 52.17 and 10 CFR Part 100. In Chapter 15 of this SER, the staff documents that the radiological consequences of bounding design-basis accidents at the outer boundary of the LPZ meet the requirements of 10 CFR 52.17.

2.2 Nearby Industrial, Transportation, and Military Facilities

2.2.1–2.2.2 Identification of Potential Hazards in Site Vicinity

For an ESP application, the applicant provides information on relative location and separation distance with respect to industrial, military, and transportation facilities and routes on the site and in its vicinity. Such facilities and routes may include air, ground, and water traffic; pipelines; and fixed manufacturing, processing, and storage facilities. Section 2.2 of the SSAR presents information concerning the industrial, transportation, and military facilities in the vicinity of the proposed ESP site. The staff's review focused on potential external hazards or hazardous materials that are present or which may reasonably be expected to be present during the projected lifetime of a nuclear power plant or plants that might be constructed on the proposed site. The staff has prepared Sections 2.2.1–2.2.2, 2.2.3, and 3.5.1.6 of this SER in accordance with the review procedures described in RS-002, using information presented in SSAR Section 2.2, responses to RAIs, and the reference materials described in the applicable sections of RS-002.

2.2.1.1–2.2.2.1 Technical Information in the Application

In SSAR Section 2.2.2.1, the applicant stated that Louisa County, Virginia, the location of the proposed site, is a rural and residential area. The applicant further stated that no substantial industrial activities occur within 5 miles of the proposed ESP site. According to the applicant, the county has granted its approval for a zoning ordinance allowing industrial development of about 620 ac near the proposed ESP site's EAB. The applicant also noted that several other areas located within 10 miles of the proposed site are zoned for industrial development, although no current plans for development exist.

Because the applicant identified a zoning ordinance, approved by the Louisa County Board of Supervisors, for industrial development of about 620 ac near the proposed site EAB, the staff requested clarification, in RAI 2.2.2-1, regarding the location of the 620-ac development. The applicant provided additional information describing the specific location of the development and the type of industrial activity that is covered by the zoning ordinance.

In Section 2.2.2.2 of the SSAR, the applicant stated that no mining activities occur within 5 miles of the proposed ESP site.

Section 2.2.2.3 of the SSAR describes the roads within 10 miles of the proposed ESP site. These consist of several Virginia State routes (Routes 208, 601, and 652), which pass no closer than 1.5 miles to the proposed site; U.S. Route 522, which passes within about 5 miles of the proposed site; and Virginia State Route 700, which provides access to the proposed site. SSAR Section 2.2.2.4 states that the Chesapeake and Ohio Railway passes within about 5.5 miles of the proposed site. In Section 2.2.2.5, the applicant stated that six marinas near the proposed ESP site provide access to pleasure craft on Lake Anna. The marina locations are between 1.4 and 2.3 miles from the proposed site. The applicant stated that no large boats or barges exist on Lake Anna.

With respect to aircraft activities in the vicinity of the proposed ESP site, the applicant described nearby airports and airways. Specifically, Table 2.2-1 of Section 2.2.2.6.1 of the SSAR lists the three airports that are within 15 miles of the proposed ESP site. Figure 2.2-1 of Section 2.2.2.6.1 of the SSAR illustrates the airport locations. Two of the three airports are within 10 miles of the proposed ESP site. In SSAR Section 2.2.2.6.2, the applicant stated that one civil airway (V223) and three military training routes (IR714, IR760, and VR1754) pass within less than 5 miles of the proposed ESP site.

In Section 2.2.2.7 of the SSAR, the applicant stated that no oil or gas pipelines are located within 5 miles of the proposed ESP site. Similarly, in Section 2.2.2.8 of the SSAR, the applicant stated that no military facilities exist within 5 miles of the proposed ESP site. Figure 2.2.1-1 illustrates the locations of nearby major roads, railroads, and gas pipelines relative to the ESP site.

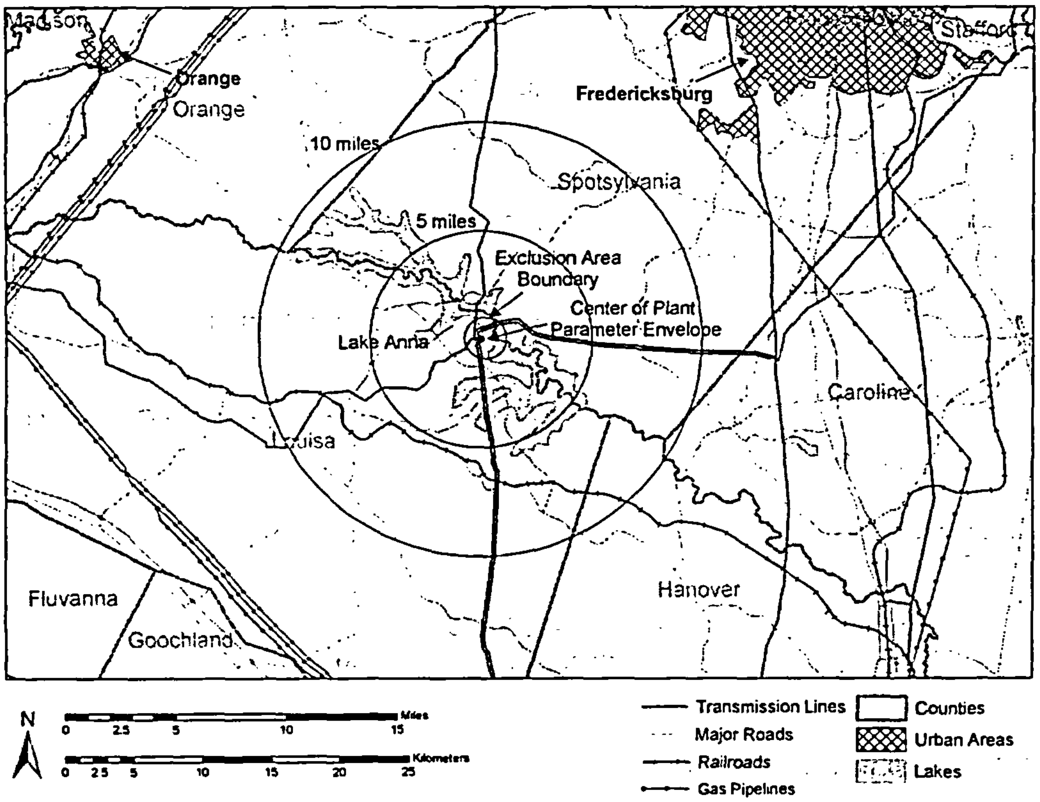


Figure 2.2.1-1 Major roads, railways, and gas pipelines in the vicinity of the ESP site

2.2.1.2–2.2.2.2 Regulatory Evaluation

In SSAR Section 1.8, the applicant identified 10 CFR 52.17(a)(1) and 10 CFR 100.20, "Factors to be Considered When Evaluating Sites," as the regulations applicable to SSAR Sections 2.2.1 and 2.2.2. In the same section, the applicant identified the following applicable NRC guidance regarding potential hazards in the vicinity of the proposed ESP site:

- RG 1.91, Revision 1, "Evaluation of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plant Sites," issued February 1978
- RG 1.78, Revision 1, "Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Chemical Release," issued December 2001
- RG 1.70, Revision 3, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, LWR Edition," issued November 1978

- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants"

- RS-002

The staff considered the following regulatory requirements in reviewing information regarding potential site hazards which would affect the safe design and siting of a nuclear power plant or plants falling within the applicant's PPE that might be constructed at the proposed site:

- 10 CFR 52.17(a)(1)(vii), with respect to information on the location and description of any nearby industrial, military, or transportation facilities and routes

- 10 CFR 100.20(b), with respect to information on the nature and proximity of man-related hazards

The following RGs identify methods acceptable to the NRC staff to meet the Commission's regulations identified above:

- RG 1.91, Revision 1
- RG 1.78, Revision 1

Sections 2.2.1–2.2.2, 2.2.3, and 3.5.1.6 of RS-002 and RG 1.70, Revision 3, provide guidance on information appropriate for identifying, describing, and evaluating potential manmade hazards.

2.2.1.3–2.2.2.3 Technical Evaluation

The staff evaluated the potential for manmade hazards in the vicinity of the proposed ESP site by reviewing (1) the information the applicant provided in Sections 2.2.1–2.2.2 of the SSAR, (2) the applicant's responses to the staff's RAIs, (3) information the staff obtained during a visit to the proposed ESP site and its vicinity, and (4) other publicly available reference material, such as U.S. Geological Survey topographic maps, satellite imagery, and geographic information system coverage files (Platts, 2004, POWER map Geographic Information System Spatial Data, including map layers of natural gas pipelines, railroads, and electric transmission lines; and Terraserver-usa.com, 2004, online 1-meter Aerial Imagery of the Lake Anna, Virginia, region). Using these data, the staff found no additional hazards beyond those the applicant identified.

The staff evaluated the information on the nearby 620-ac development that the applicant provided in its response to RAI 2.2.1-1. Included among the 30 industrial uses permitted for this area are "acetylene gas manufacture on a commercial scale," "fireworks or explosives manufacture, nitrating process, the loading of explosives, or their storage in bulk," "petroleum refining," and "sulphurous, sulphuric, nitric or hydrochloric or other corrosive or offensive acid manufacture, or their use or storage, except on a limited scale (by conditional use permit) as accessory to a permitted industry." Pursuant to this ordinance, an entity seeking permission for a specific industrial use must apply for and obtain a "conditional use permit" from the Louisa County Planning Commission. The request for a permit may be denied by the planning commission, the governing body, if there is a finding that the use would be detrimental to the health and safety of the public.

Currently, there have been no hazardous industrial facilities identified on this site. Hence, the site does not pose any industrial hazard at the present time. In the event that some industrial use were implemented on the site, any hazard determination would be based upon specific information regarding the nature of the hazard, as well as specific nuclear plant design parameters, neither of which are available at this time. On this basis, the staff finds that the 620 ac site currently does not present any identifiable hazards, and an evaluation of industrial hazards, if any, associated with the site can be performed, if warranted, should a CP or COL application referencing any ESP issued for the North Anna site be submitted. This is **COL Action Item 2.2-1.**

2.2.1.4–2.2.2.4 Conclusions

As set forth above, the applicant has provided information in the SSAR regarding potential site hazards in accordance with the guidance of RG 1.70, such that compliance with the requirements of 10 CFR 100.20 and 10 CFR 100.21, "Non-Seismic Site Criteria," can be evaluated. The applicant has reviewed the nature and extent of activities involving potentially hazardous materials conducted on or in the vicinity of the site to identify hazards that might pose undue risk to a facility falling within the applicant's PPE that might be constructed on the proposed site. Based on its evaluation of the information presented in the SSAR, as well as information the staff obtained independently, the staff concludes that all potentially hazardous activities on and in the vicinity of the site have been identified. Sections 2.2.3 and 3.5.1.6 of this SER discuss the evaluation of such hazards.

2.2.3 Evaluation of Potential Accidents

2.2.3.1 Technical Information in the Application

In SSAR Section 2.2.3, the applicant evaluated earth-bound and aircraft hazards. Section 3.5.1.6 of this SER discusses the staff's evaluation of aircraft hazards.

Consistent with its identification of potential hazards in SSAR Sections 2.2.1 and 2.2.2, the applicant limited its evaluation of earth-bound hazards to the effects of explosion and formation of flammable vapor clouds from nearby sources. The applicant stated that the largest explosive load routinely transported by truck on Virginia highways contains 8500 gallons (gal) of gasoline. The explosive force of this quantity of gasoline is estimated to be equivalent to 50,700 pounds (lb) of TNT, using a simple TNT-equivalent yield formula. The applicant, citing the methodology of RG 1.91, concluded that, if this amount of gasoline were to explode, a peak overpressure of 1 pound per square inch (psi) would be experienced as far as 1900 ft away from the point of explosion. The closest point of Virginia Route 652 to the ESP site is 1.5 miles (6420 ft). The applicant noted that RG 1.91 cites 1 psi as a conservative value of peak positive incident overpressure, below which no significant damage would be expected. Thus, the applicant concluded that no significant damage would occur in the event of an explosion resulting from a gasoline truck traffic accident.

The applicant did not evaluate pipeline hazards because no natural gas pipeline or mining facilities are located within 10 miles of the ESP site, and no pipelines carrying potentially hazardous materials are located within 5 miles of the ESP site. Therefore, the applicant concluded that the potential for hazards from these sources that could adversely affect safe operation of the plant is minimal.

In RAI 2.2.3-1, the staff asked the applicant to describe whether the existing NAPS units pose any undue risk to a nuclear power plant or plants falling within the applicant's PPE that might be constructed and operated on the proposed ESP site. In its response, the applicant stated that no such hazards exist.

2.2.3.2 Regulatory Evaluation

In SSAR Sections 1.8 and 2.2, the applicant identified the following applicable NRC guidance regarding potential hazards in the vicinity of the proposed ESP site:

- RG 1.91, Revision 1
- RG 1.78, Revision 1
- RG 1.70, Revision 3
- NUREG-0800
- RS-002

In SSAR Section 1.8, the applicant identified the regulation applicable to SSAR Section 2.2.3 as 10 CFR 100.20. It also identified the requirements of RS-002 as applicable.

The staff considered the following regulatory requirements in reviewing information regarding potential site hazards which would affect the safe design and siting of a nuclear power plant or plants falling within the applicant's PPE that might be constructed at the proposed site:

- 10 CFR 52.17(a)(1)(vii), with respect to information on the location and description of any nearby industrial, military, or transportation facilities and routes

- 10 CFR 100.20(b), with respect to information on the nature and proximity of man-related hazards

- 10 CFR 100.21(e), with respect to the evaluation of potential hazards associated with nearby transportation routes and industrial and military facilities

The following RGs identify methods acceptable to the NRC staff to meet the Commission's regulations identified above:

- RG 1.91, Revision 1
- RG 1.78, Revision 1

Sections 2.2.1–2.2.2, 2.2.3, and 3.5.1.6 of RS-002 and RG 1.70 provide guidance on information appropriate for identifying, describing, and evaluating potential manmade hazards.

2.2.3.3 *Technical Evaluation*

The staff reviewed the applicant's analysis of the effects of potential explosions and the formation of flammable vapor clouds. The only potential source of explosions or flammable vapor clouds within 5 miles of the proposed site is truck traffic on the nearby highways. According to the applicant, the largest explosive load routinely transported by truck on Virginia highways contains 8500 gal of gasoline. The staff has previously reviewed and evaluated the explosive yield from this quantity of gasoline, as documented in the UFSAR for the existing NAPS. The resulting TNT equivalent was found to be 50,700 lb, which yields a peak overpressure of 1 psi at 1,900 ft from the point of explosion. Since the closest highway (Virginia Route 652) is 6429 ft from the proposed ESP site, the potential peak overpressure at the proposed site would be less than 1 psi. Hence, using the criteria of RG 1.91, no significant damage to safety-related SSCs that may be located on the proposed site would be expected.

The staff evaluated the information in the SSAR regarding the location of the ESP site relative to the location of the existing NAPS units and the applicant's response to RAI 2.2.3-1. In its response to this RAI, the applicant stated that it did not identify any hazards with respect to NAPS Units 1 and 2 that would pose an undue risk to a nuclear power plant or plants that might be constructed on the ESP site.

The staff independently reviewed possible hazards posed by the existing NAPS units. This review did not identify any hazards that would preclude the provision of protective or mitigative design features for a nuclear power plant or plants to be constructed on the ESP site. This view is supported by the fact that the staff found, during the licensing review for NAPS Units 1 and 2, that design features of those units would adequately protect the NAPS units against identified hazards (e.g., release of toxic or flammable materials, internal and external missiles). Design-specific interactions between the existing and new units would need to be evaluated and, if necessary, addressed at the COL stage. The need for consideration of design-specific hazards interactions is **COL Action Item 2.2-2.**

2.2.3.4 *Conclusions*

As set forth above, the applicant has identified potential accidents related to the presence of hazardous materials or activities on and near the proposed ESP site which could affect a nuclear power plant falling within the applicant's PPE. The staff finds that the applicant has selected those potential accidents which should be considered as design-basis events at the COL stage, in accordance with 10 CFR Part 100. The staff also finds that the applicant has identified and evaluated hazards from nearby facilities such that the staff concludes that such facilities pose no undue risk to the type of facility proposed for the site, subject to confirmation at the COL stage regarding design-specific hazards interactions. Therefore, the staff concludes that the site location is acceptable with regard to potential accidents that could affect such a facility and that it meets the requirements of 10 CFR 52.17(a)(1)(vii), 10 CFR 100.20(b), and 10 CFR 100.21(e).

2.3 Meteorology

To ensure that a nuclear power plant or plants could be designed, constructed, and operated on an applicant's proposed ESP site in compliance with the Commission's regulations, the NRC staff evaluates regional and local climatological information, including climate extremes and severe weather occurrences that may affect the design and siting of a nuclear plant. The staff reviews information concerning atmospheric dispersion characteristics of a nuclear power plant site to determine whether the radioactive effluents from postulated accidental releases, as well as routine operational releases, are within Commission guidelines. The staff has prepared Sections 2.3.1 through 2.3.5 of this SER in accordance with the review procedures described in RS-002, using information presented in SSAR Section 2.3, responses to staff RAIs, and generally available reference materials, as described in the applicable sections of RS-002.

2.3.1 Regional Climatology

2.3.1.1 Technical Information in the Application

In this section of the SSAR, the applicant presented information concerning the averages and the extremes of climatic conditions and regional meteorological phenomena that could affect the design and siting of a nuclear power plant that falls within the applicant's PPE and that might be constructed on the proposed site. The applicant provided the following information:

- a description of the general climate of the region with respect to types of air masses, synoptic features (high- and low-pressure systems and frontal systems), general airflow patterns (wind direction and speed), temperature and humidity, precipitation (rain, snow, and sleet), and relationships between synoptic-scale atmospheric processes and local (site) meteorological conditions

- seasonal and annual frequencies of severe weather phenomena, including tornadoes, waterspouts, thunderstorms, lightning, hail (including probable maximum size), and high air pollution potential

- meteorological site characteristics to be used as minimum design and operating bases, including the following:

  - the maximum snow and ice load (water equivalent) on the roofs of safety-related structures

  - the ultimate heat sink (UHS) meteorological conditions resulting in the maximum evaporation and drift loss of water and minimum water cooling

  - the tornado parameters, including translational speed, rotational speed, and the maximum pressure differential with the associated time interval

  - the 100-year return period straight-line winds

  - other meteorological conditions to be used for design- and operating-basis considerations

The applicant characterized the regional climatology pertinent to the North Anna ESP site using data reported by the National Weather Service (NWS) at the Richmond, Virginia, first-order weather station, as well as nearby cooperative observer stations, such as Louisa, Partlow, and

Piedmont, Virginia. The applicant obtained information on severe weather from a variety of sources, including publications by the National Climatic Data Center (NCDC), the American Society of Civil Engineers (ASCE), the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), and the American National Standards Institute (ANSI).

The North Anna ESP site is located in the eastern Piedmont climatic division of Virginia. According to the applicant, the climate can be described as modified continental; the summers are warm and humid, and the winters are generally mild. The Blue Ridge Mountains to the west act as a potential barrier to outbreaks of cold, continental air in winter. The open waters of the Chesapeake Bay and the Atlantic Ocean contribute to the humid summers and mild winters.

Temperatures in the site region rarely exceed 100 °F or fall below 0 °F. Table 2.3.1-1 presents the applicant's dry-bulb and wet-bulb site characteristics for the North Anna ESP site, based on temperature and humidity data recorded at the Richmond weather station.

Table 2.3.1-1 Applicant's Proposed Ambient Air Temperature and Humidity Site Characteristics

SITE CHARACTERISTIC		VALUE	DESCRIPTION
Maximum Dry-Bulb Temperature	2% annual exceedance	90 °F with 75 °F concurrent wet bulb	Wet-bulb and dry-bulb temperatures associated with the listed exceedance values and the 100-year return period
	0.4% annual exceedance	95 °F with 77 °F concurrent wet bulb	
	0% annual exceedance	104.9 °F with 79 °F concurrent wet bulb	
	100-year return period	109 °F	
Minimum Dry-Bulb Temperature	1% annual exceedance	18 °F	
	0.4% annual exceedance	14 °F	
	100-year return period	-19 °F	
Maximum Wet-Bulb Temperature	0.4% annual exceedance	79 °F	
	0% annual exceedance	84.9 °F	
	100-year return period	88 °F	

The applicant stated that the area around the site receives an annual average rainfall of approximately 44 inches (in.). Rainfall is fairly well distributed over the entire year, with the exception of July and August when thunderstorm activity raises the monthly totals. Extra-tropical storms can also contribute significantly to precipitation during September.

Richmond, Virginia, averages about 12.4 in. of snow a year. Snow generally remains on the ground for only 1 or 2 days, although durations of a week or more have occurred as a result of heavy snowfall events immediately followed by cold weather patterns.

According to the applicant, the general synoptic conditions typically predominate in regard to climatic characteristics of the site region. However, during periods of extreme temperatures or light-wind conditions, the local conditions have an influence on the site's meteorology. Nearby Lake Anna has a moderating effect with respect to extreme temperatures in the immediate vicinity of the site. The Blue Ridge Mountains to the west also tend to channel winds along a general north-south orientation during light-wind conditions.

In Revision 0 to the SSAR, the applicant stated that the extreme fastest-mile wind speed at 30 ft above the ground (100-year return period) is 80 miles per hour (mi/hr), with a fastest-mile wind speed value of 68 mi/hr recorded at Richmond during the period 1958–1989. In RAI 2.3.1-1, the staff asked the applicant to provide a 3-second (s) gust wind speed that represents a 100-year return period. In response to RAI 2.3.1-1, the applicant provided a 3-s gust wind speed value of 96 mi/hr, which represents a 100-year return period at 33 ft above the ground.

In Revision 3 to the SSAR, the applicant revised its extreme fastest-mile 100-year return period wind speed value to 64 mi/hr, based on a calculated value reported for Richmond by ANSI A58.1-1982, "Minimum Design Loads for Buildings and Other Structures." In Revision 3 to the SSAR, the applicant identified the 64 mi/hr fastest-mile wind speed value as a basic wind speed site characteristic.

In Open Item 2.3-1, the staff stated that the applicant's revised 100-year return period fastest-mile basic wind speed site characteristic of 64 mi/hr is not conservative when compared to the minimum 50-year return period fastest-mile basic wind speed value of 70 mi/hr specified in Section 6.5.2 of ANSI A58.1-1982. The applicant's chosen fastest-mile basic wind speed site characteristic of 64 mi/hr is also not conservative when compared to the highest fastest-mile wind speed value of 68 mi/hr recorded at Richmond during the 32-year period 1958–1989. In its submittal dated March 3, 2005, the applicant responded to Open Item 2.3-1 by proposing that the 3-s gust wind speed value of 96 mi/hr be used as the basic wind speed site characteristic instead of the 64 mi/hr fastest-mile wind speed value. Table 2.3.1-2 presents the applicant's revised proposed basic wind speed site characteristic.

Table 2.3.1-2 Applicant's Proposed Basic Wind Speed Site Characteristic

SITE CHARACTERISTIC	VALUE	DESCRIPTION
Basic Wind Speed	96 mi/hr	3-s gust wind velocity associated with a 100-year return period at 33 ft above ground level in the site area

In RAIs 2.3.1-1 and 2.3.1-6, the staff asked the applicant to provide additional information regarding site characteristic tornado data and the methodology used for determining tornado characteristics. In its response, the applicant stated that a total of 235 tornadoes were reported within a 2-degree square area around the North Anna ESP site (i.e., an area enclosed by 2-degree longitudinal and latitudinal lines centered on the North Anna ESP site) during the period 1950–2003. The applicant used these data to calculate the annual probability of a tornado striking a point within this 2-degree square area as 5.94×10^{-5} per year. This is equivalent to a tornado mean recurrence interval of 16,835 years. The applicant also used these data to generate the tornado site characteristics (based on a 10^{-7} per year occurrence), shown in Table 2.3.1-3.

Table 2.3.1-3 Applicant's Proposed Tornado Site Characteristics

SITE CHARACTERISTIC	VALUE	DESCRIPTION
Maximum Wind Speed	260 mi/hr	Sum of the maximum rotational and maximum translation wind speed components at the site, due to passage of a tornado having a probability of occurrence of 10^{-7} per year
Maximum Translational Speed	52 mi/hr	Translation component of maximum wind speed at the site, due to the movement across ground of a tornado having a probability of occurrence of 10^{-7} per year
Maximum Rotational Speed	208 mi/hr	Rotation component of maximum wind speed at the site, due to passage of a tornado having a probability of occurrence of 10^{-7} per year
Radius of Maximum Rotational Speed	150 ft	Distance from the center of the tornado at which the maximum rotational wind speed occurs at the site, due to passage of a tornado having a probability of occurrence of 10^{-7} per year
Maximum Pressure Drop	1.5 lbf/in.^{2}	Decrease in ambient pressure from normal atmospheric pressure at the site, due to passage of a tornado having a probability of occurrence of 10^{-7} per year
Maximum Rate of Pressure Drop	0.76 lbf/in.^{2}/s	Maximum rate of pressure drop at the site, due to passage of a tornado having a probability of occurrence of 10^{-7} per year

The SSAR states that, on average, a tropical cyclone or its remnants can be expected to impact some part of Virginia each year. As stated in the SSAR, the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center hurricane database reports that 55 tropical cyclone centers or storm tracks have passed within a 100-nautical mile (nmi) radius of the North Anna ESP site from 1851 through 2003. Table 2.3.1-4 presents the storm classifications and respective frequencies of these tropical cyclone occurrences over this period.

Table 2.3.1-4 Tropical Cyclones Reported within 100-Nautical Mile Radius of the North Anna ESP Site from 1851 through 2003

CLASSIFICATION	NUMBER OF OCCURRENCES	MAXIMUM SUSTAINED WIND SPEED RANGE
Category 3 Hurricane	1	111–130 mi/hr
Category 2 Hurricane	1	96–110 mi/hr
Category 1 Hurricane	5	74–95 mi/hr
Tropical Storm	27	39–73 mi/hr
Tropical Depression	13	≤38 mi/hr
Subtropical Depression	1	≤38 mi/hr
Extra-Tropical Storm	7	undefined

According to the applicant, tropical cyclones are responsible for the following record rainfall events in the North Anna ESP site area:

- In August 1969, Hurricane Camille (a tropical depression by the time it passed within 100 nmi of the North Anna ESP site) resulted in a record 24-hour rainfall of 11.18 in. at the Louisa cooperative weather station. The SSAR notes that this is the overall highest 24-hour rainfall total recorded at any station in the North Anna ESP site area.

- In August 1955, Hurricane Connie (a tropical storm by the time it passed within 120 nmi of the North Anna ESP site) resulted in a record 24-hour rainfall total of 8.79 in. at Richmond.

According to the applicant, the occurrence of snowfalls greater than or equal to 1 in. in the North Anna ESP site area ranges from about 3 to 5 days per year. Daily snowfall totals greater than or equal to thresholds of 5 in. and 10 in. occur less than 1 day per year. The applicant reported maximum 24-hour and monthly snowfall totals for the North Anna ESP site region of 21.6 in. at Richmond in January 1940 and 41.0 in. at Partlow in January 1966, respectively. The applicant reported the weight of the 100-year return period snowpack for the North Anna ESP site area as 30.5 pound-force per square foot (lbf/ft^2) and the 48-hour winter probable maximum precipitation (also known as the probable maximum winter precipitation (PMWP)) as 20.75 in. In response to Open Item 2.3-2, the applicant also reported a maximum ground snow load of 45.4 lbf/ft^2 as the weight of the 100-year snowpack plus 48-hour maximum snowfall. As shown in Table 2.3.1-5, the applicant selected the 100-year return period snowpack value of 30.5 lbf/ft^2, the 100-year snowpack plus 48-hour maximum snowfall value of 45.4 lbf/ft^2, and the 48-hour PMWP value of 20.75 in. as winter precipitation site characteristics for use in the design of the roofs of safety-related structures.

Table 2.3.1-5 Applicant's Proposed Winter Precipitation Site Characteristics

SITE CHARACTERISTIC	VALUE	DESCRIPTION
100-Year Snowpack	30.5 lbf/ft^2	Weight, per unit area, of the 100-year return period snowpack at the site
100-Year Snowpack plus 48-Hour Maximum Snowfall	45.5 lbf/ft^2	48-hour maximum snowfall (28.5 in. = 15 lbf/ft^2 on top of 100-year return snowpack (30.5 lbf/ft^2)
48-Hour Winter Probable Maximum Precipitation	20.75 in.	Maximum probable winter rainfall in a 48-hour period

According to the applicant, data published by the NCDC show that Louisa and Spotsylvania Counties can expect, on average, hail with diameters greater than or equal to 0.75 in. about 1 day per year. Nearby counties to the south and east of the North Anna ESP site can expect hail with diameters greater than or equal to 0.75 in. to occur from 1 to 2 days per year. Hail events with diameters up to 1.75 in. have been reported in recent years in both Louisa and Spotsylvania Counties, four in Louisa County in 1998 and three in Spotsylvania County in 1993. Softball-size hail (about 4.5 in. in diameter) has been observed in recent years at two locations in the general North Anna ESP site area—once in Free Union, Virginia (approximately 42 miles west of the ESP site) on June 4, 2002, and once in Lignum, Virginia (approximately 28 miles north-northwest of the ESP site), on May 4, 1996.

The applicant estimated that, on average, 36 thunderstorm-days per year occur in the site area, resulting in an estimated 11.2 lightning flashes to earth per square mile per year. Given the frequency of thunderstorms and the size of the North Anna ESP site PPE (site footprint within which any new reactors would be located) (0.068 mi^2), the expected frequency of lightning flashes in the PPE is 0.76 per year.

According to the applicant, low-level inversions in the North Anna ESP site region based at or below an elevation of 500 ft occur during approximately 30 percent of the year. Most of these inversions are nocturnal in nature, generated through nighttime cooling. These inversions occur most frequently during the autumn and winter seasons and least frequently during the spring and summer seasons. Likewise, the autumn and winter seasons have the greatest frequency of occurrence of shallow mixing depths, with autumn and winter having afternoon mean maximum mixing height depths of about 4600 ft and 3300 ft, respectively.

The applicant examined temperature and humidity data from Richmond (1978–2003) to determine the meteorological site characteristics for the UHS in accordance with RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants," issued January 1976. The applicant stated that the controlling parameters for the type of UHS selected by the applicant (i.e., a mechanical draft cooling tower over a buried water storage basin or other passive water storage facility) are the wet-bulb temperature and the coincident dry-bulb temperature. The applicant considered the worst (i.e., highest) 30-day daily average of wet-bulb temperatures and coincident dry-bulb temperatures to represent the meteorological conditions resulting in maximum evaporation and drift loss. Likewise, the applicant considered the worst (i.e., highest) 1-day and 5-day daily average of wet-bulb temperatures and coincident dry-bulb temperatures to conservatively represent the meteorological conditions resulting in minimum water cooling. Consequently, the applicant calculated the worst 1-day, worst 5-day, and worst 30-day daily average wet-bulb temperatures and coincident dry-bulb temperatures as UHS meteorological site characteristics values. Table 2.3.1-6 presents these results.

In Open Item 2.3-3, the staff identified the need for an additional UHS meteorological site characteristic for use in evaluating the potential for water freezing in the UHS water storage facility, a phenomenon which would reduce the amount of water available for use by the UHS. In its submittal dated March 3, 2005, the applicant responded to Open Item 2.3-3 by proposing use of the maximum cumulative degree-days below freezing as the relevant site characteristic. The applicant proposed a maximum cumulative degree-day below freezing site characteristic value of 322 °F degree-days, based on the maximum value derived from December 1 through March 31 for the period 1949–2001, using daily mean air temperatures recorded at Piedmont.

Table 2.3.1-6 Applicant's Proposed Ultimate Heat Sink Meteorological Site Characteristics

SITE CHARACTERISTIC	VALUE	DESCRIPTION
Worst 1-Day Daily Average of Wet-Bulb Temperatures and Coincident Dry-Bulb Temperatures	78.9 °F wet-bulb temperature with coincident 87.7 °F dry-bulb temperature	Meteorological conditions resulting in the minimum water cooling during any 1 day
Worst 5-Day Daily Average of Wet-Bulb Temperatures and Coincident Dry-Bulb Temperatures	77.6 °F wet-bulb temperature with coincident 80.9 °F dry-bulb temperature	Meteorological conditions resulting in the minimum water cooling during any consecutive 5 days
Worst 30-Day Daily Average of Wet-Bulb Temperatures and Coincident Dry-Bulb Temperatures	76.3 °F wet-bulb temperature with coincident 79.5 °F dry-bulb temperature	Meteorological conditions resulting in the maximum evaporation and drift loss during any consecutive 30 days
Maximum Cumulative Degree-Days Below Freezing	322 °F degree-days	Meteorological condition resulting in the maximum formation of surface ice in the UHS basin

2.3.1.2 Regulatory Evaluation

In SSAR Section 1.8.1, the applicant identified the following applicable NRC regulations regarding regional climatology:

- Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena," with respect to information on severe regional weather phenomena that have historically been reported for the region and that are reflected in the design bases for SSCs important to safety

- Appendix A to 10 CFR Part 50, GDC 4, "Environmental and Dynamic Effects Design Bases," with respect to information on tornadoes that could generate missiles

- 10 CFR 100.20(c) and 10 CFR 100.21(d) with respect to the consideration that has been given to the regional meteorological characteristics of the site

In SSAR Sections 1.8.2 and 2.3.1, the applicant identified the following applicable NRC guidance regarding regional climatology:

- RG 1.27 with respect to the meteorological conditions that should be considered in the design of the UHS

- Section 2.3.1 of RG 1.70 with respect to the type of general climate and regional meteorological data that should be presented

- RG 1.76, "Design Basis Tornado for Nuclear Power Plants," issued April 1974, with respect to the characteristics of the design-basis tornado

The staff has reviewed this portion of the application in accordance with the guidance identified by the applicant, and to determine if the application is in compliance with the identified regulations, with the exception of the GDC. An ESP applicant need not demonstrate compliance with the GDC with respect to regional climatology.

Section 2.3.1 of RS-002 and Section 2.3.1 of RG 1.70 provide the following guidance on information appropriate for determining regional climatology:

- The description of the general climate of the region should be based on standard climatic summaries compiled by NOAA. Consideration of the relationships between regional synoptic-scale atmospheric processes and local (site) meteorological conditions should be based on appropriate meteorological data.

- Data on severe weather phenomena should be based on standard meteorological records from nearby representative NWS, military, or other stations recognized as standard installations that long periods of data on record. The applicability of these data to represent site conditions during the expected period of reactor operation should be substantiated.

- Tornado site characteristics may be based on RG 1.76 or the staff's interim position on design-basis tornado characteristics (see letter dated March 25, 1988, from the NRC to the Advanced-Light Water Reactor Utility Steering Committee). An ESP applicant may specify any tornado wind speed site characteristics that are appropriately justified, provided that a technical evaluation of site-specific data is conducted.

- Basic (straight-line) wind speed site characteristics should be based on appropriate standards, with suitable corrections for local conditions.

- The UHS meteorological data, as stated in RG 1.27, should be based on long-period regional records which represent site conditions. Suitable information may be found in climatological summaries for the evaluation of wind, temperature, humidity, and other meteorological data used for UHS design.

- Freezing rain estimates should be based on representative NWS station data.

- High air pollution potential information should be based on U.S. Environmental Protection Agency (EPA) studies.

- All other meteorological and air quality data to be used for safety-related plant design and operating bases should be documented and substantiated.

2.3.1.3 Technical Evaluation

The staff evaluated regional meteorological conditions using information reported by the NCDC, the National Severe Storms Laboratory (NSSL), the Southern Regional Climate Center (SRCC), ASHRAE, ASCE, and the Structural Engineering Institute (SEI). The staff reviewed statistics for the following climatic stations located in the vicinity of the North Anna ESP site:

- Partlow, Virginia, located approximately 5 miles east of the ESP site
- Louisa, Virginia, located approximately 11 miles west of the ESP site
- Piedmont, Virginia, located approximately 21 miles west-northwest of the ESP site
- Richmond, Virginia, located approximately 47 miles southeast of the ESP site
- Charlottesville, Virginia, located approximately 36 miles west of the ESP site

Normal climatic data for the period 1971–2000 reported by NCDC for the eastern Piedmont climatic division of Virginia indicate that the annual mean temperature in the area is about 56.6 °F and ranges from a low monthly mean value of about 35.9 °F in January to a high monthly mean value of about 76.8 °F in July (NCDC, "Eastern Piedmont, Virginia, Divisional Normals—Temperature, Period 1971–2000, Climatography of the United States No. 85"). One of the highest temperatures recorded in the site region was 106 °F at Partlow on both August 31 and September 2, 1953 (SRCC, "Partlow, Virginia, Period of Record Monthly Climate Summary, Period of Record: 06/01/1952 to 12/31/1976"); one of the lowest temperatures recorded in the site region was -21 °F at Louisa on February 5, 1996 (SRCC, "Louisa, Virginia, Period of Record Monthly Climate Summary, Period of Record: 08/01/1948 to 03/31/2004").

The annual mean wet-bulb temperature at Richmond is 52.3 °F, ranging from a high monthly mean value of 71.5 °F in July to a low monthly mean value of 34.3 °F in January. The annual mean relative humidity is 70 percent (NCDC, "Richmond, Virginia, 2002 Local Climatological Data, Annual Summary with Comparative Data").

For the reasons set forth below, the staff concurs with the temperature and humidity site characteristics presented by the applicant. The applicant's 2- and 0.4-percent annual exceedance maximum dry-bulb temperatures, the 1- and 0.4-percent annual exceedance minimum dry-bulb temperatures, and the 0.4 percent exceedance maximum wet-bulb temperatures are based on Richmond data published by the NCDC ("Engineering Weather Data CDROM").[1] The applicant's 0-percent annual exceedance maximum dry-bulb and maximum wet-bulb temperatures represent the highest values recorded at Richmond during the period 1973–2002. The 100-year return period maximum dry-bulb and maximum wet-bulb temperatures provided by the applicant were extrapolated from the Richmond 1973–2002 data using a least squares regression method, as described in the applicant's response to NRC RAI 2.3.1(b). In order to verify the applicant's 100-year return period data, the staff also calculated 100-year return period maximum dry-bulb and maximum wet-bulb temperatures using NCDC data for Richmond during the period 1961–1990 (NCDC, "Solar and Meteorological Surface Observational Network (SAMSON) for Eastern U.S. CDROM") and algorithms based on the Gumbel Type 1 extreme value distribution as defined in Chapter 27 of

[1]The data presented by the applicant as the 1- and 0.4-percent annual exceedance minimum dry-bulb temperatures are equivalent to the NCDC 99- and 99.6-percent annual exceedance (i.e., occurrence) values.

the 2001 ASHRAE Handbook—Fundamentals. The staff found that the 100-year return period maximum dry-bulb and maximum wet-bulb temperature values calculated by the applicant bound the equivalent values calculated by the staff.

The staff chose not to list the applicant's 0-percent annual exceedance maximum dry-bulb and wet-bulb temperatures as site characteristics because these values are dependent upon the length of the available period of record. The staff presented 100-year return period values instead.

According to the 1971–2000 normal climatic data reported by NCDC for the eastern Piedmont climatic division of Virginia ("Eastern Piedmont, Virginia, Divisional Normals—Precipitation, Period 1971–2000, Climatography of the United States No. 85"), precipitation is well distributed throughout the year, with monthly climate division normals for the North Anna ESP site region ranging from a minimum of about 3.18 in. in December to a maximum of about 4.36 in. in July. In September 1987, Charlottesville experienced one of the highest monthly amounts of precipitation observed in the area—17.96 in. (SRCC, "Charlottesville, Virginia, Period of Record Monthly Climate Summary, Period of Record: 08/05/1948 to 03/31/2004"). On August 20, 1969, Louisa recorded one of the highest 24-hour precipitation totals for the site region—11.18 in. (SRCC, "Louisa, Virginia, Period of Record Monthly Climate Summary, Period of Record: 08/01/1948 to 03/31/2004"). This rainfall was associated with Hurricane Camille.

Snowfall in the site vicinity averages approximately 16.6 in. per year, based on historical data collected during 1952–1976 at the Partlow cooperative weather station (SRCC, "Partlow, Virginia, Period of Record Monthly Climate Summary, Period of Record: 06/01/1952 to 12/31/1976"). Measurable snowfall has occurred from November through April, with the most snow typically falling in January (5.7 in. on average in Partlow).

Damaging storms occur mainly from snow and freezing rain in winter, and from hurricanes, tornadoes, and severe thunderstorms in other seasons (NCDC, "Richmond, Virginia, 2002 Local Climatological Data, Annual Summary with Comparative Data"). Damage may be caused by wind, flooding, or rain, or by any combination of these. Tornadoes are infrequent, but some occurrences have been observed within the area.

The applicant presented a 100-year return period fastest-mile wind speed value of 64 mi/hr in Revision 3 to the SSAR. The applicant's chosen 100-year return period fastest-mile wind speed is not conservative when compared to the minimum 50-year return period fastest-mile basic wind speed of 70 mi/hr specified in Section 6.5.2 of ANSI A58.1-1982. The applicant's chosen value is also not conservative when compared to the highest fastest-mile wind speed of 68 mi/hr recorded at Richmond during the 32-year period of record, 1958–1989. Consequently, the staff does not endorse the use of the 64 mi/hr 100-year return period fastest-mile wind speed value as a basic wind speed site characteristic. This concern resulted in Open Item 2.3-1.

In its response to Open Item 2.3-1, the applicant proposed using a 100-year return period 3-s gust wind speed value of 96 mi/hr as the basic wind speed site characteristic. The applicant determined this value in accordance with the guidance provided by the ASCE and the SEI industry standard on building loads ("Minimum Design Loads for Buildings and Other Structures," SEI/ASCE 7-02). Therefore, the staff concludes that a 3-s gust wind speed site characteristic of 96 mi/hr is acceptable.

According to NSSL (NCDC, "Severe Thunderstorm Climatology, Total Threat"), the mean number of days per year with the threat of tornados occurring within 25 miles of the North Anna ESP site is approximately 0.4 to 0.6 for any tornado, approximately 0.05 to 0.10 for a significant tornado (F2 or greater; wind speeds in excess of 113 mi/hr), and less than 0.005 for a violent tornado (F4 or greater; wind speeds in excess of 207 mi/hr).

At the NRC's direction, Pacific Northwest National Laboratories (PNNL) prepared a technical evaluation report evaluating the tornado site characteristics for the North Anna ESP site (Ramsdell, Jr., V.J., "Technical Evaluation Report on Design Basis Tornadoes for the North Anna ESP Site"). This report derived a best estimate annual tornado strike probability of 1.6×10^{-4}, based on tornado data from the period January 1950 through August 2003. This probability corresponds to a mean recurrence interval of 6250 years. Using a slightly different methodology and period of record, the applicant calculated a similar but higher tornado return period of 16,835 years. The PNNL report also derived a best estimate 10^{-7} per year occurrence tornado site characteristics wind speed of 245 mi/hr, which is bounded by the applicant's tornado site characteristics wind speed of 260 mi/hr. The applicant derived the remaining tornado site characteristics (i.e., pressure drop and rate of pressure drop) assuming the radius of the maximum rotational wind speed is 150 ft and the ratio between the rotational wind speed and the translational wind speed is 4. These assumptions are consistent with the staff's interim position on design-basis tornado characteristics. Therefore, the staff concludes that the applicant's tornado site characteristics are acceptable.

During the period 1900–2002, a total of 4 hurricanes and 17 tropical storms directly hit Virginia (Landreneau, D., "Atlantic Tropical Storms and Hurricanes Affecting the United States: 1899–2002," NOAA Technical Memorandum NWS SR-206 (updated through 2002)). These storms typically weaken as they move inland, so wind damage is usually confined to the coastal regions, while damage inland comes primarily from heavy rain and flooding. One of the most significant tropical cyclones to affect portions of east-central Virginia during the last several decades was Hurricane Isabel on September 18–19, 2003. Isabel made landfall near Drum Inlet, North Carolina, as a Category 2 hurricane (maximum sustained winds between 96 and 100 mi/hr), then weakened to a tropical storm over southern Virginia as it tracked northwest into central Virginia, just west of Richmond. The highest sustained wind speed recorded at Richmond was 38 mi/hr; the highest gust recorded at Richmond was 73 mi/hr. The unusually large wind field resulted in the most extensive power outages ever experienced in Virginia. Inland flooding also resulted from rainfall amounts ranging from 4 to 7 in., which occurred over parts of the Piedmont regions of central and south central Virginia (Beven, J., and H. Cobb, "Tropical Cyclone Report, Hurricane Isabel, 6–19 September 2003," National Hurricane Center and NCDC Storm Event Database, "Storm Events for Virginia, 01/01/1950 through 04/30/2004"). Although Hurricane Isabel had a significant impact on the ESP site region, it did not result in any recordbreaking wind or rainfall statistics and, as such, has no impact on the climatic site characteristics of the North Anna ESP site.

The highest monthly and annual total snowfalls recorded at the Partlow station were 41 in. and 54 in., respectively. One of the highest reported 24-hour snowfall observations in the site region was 21.6 in. in January 1940 at Richmond (NCDC, "Richmond, Virginia, 2002 Local Climatological Data, Annual Summary with Comparative Data"). One of the highest snow depths recorded in the site region was 24 in. on January 26, 1987, and on January 30, 1966, in Louisa (SRCC, "Louisa, Virginia, Period of Record Monthly Climate Summary, Period of Record: 08/01/1948 to 03/31/2004").

RG 1.70 specifies both the weight of the 100-year return period snowpack and the weight of the 48-hour PMWP to assess the potential snow loads on the roofs of safety-related structures. The staff's interim position on winter precipitation loads (see memorandum dated March 24, 1975, from H. R. Denton to R. R. Maccary) provides clarification as to the load combinations to be used in evaluating the roofs of safety-related structures. Consistent with the staff's interim position on winter precipitation loads, the winter precipitation loads to be included in the combination of normal live loads to be considered in the design of a nuclear power plant or plants that might be constructed on a proposed ESP should be based on the weight of the 100-year snowpack or snowfall, whichever is greater, recorded at ground level. Likewise, the winter precipitation loads to be included in the combination of extreme live loads to be considered in the design of a nuclear power plant or plants that might be constructed on a proposed ESP should be based on the weight of the 100-year snowpack at ground level plus the weight of the 48-hour PMWP at ground level for the month corresponding to the selected snowpack. A COL or CP applicant may choose and justify an alternative method for defining the extreme winter precipitation load by demonstrating that the 48-hour PMWP could neither fall nor remain on the top of the snowpack and/or building roofs.

The applicant has identified a 100-year return period snowpack of 30.5 lbf/ft^2 for the North Anna ESP site. The applicant determined this value in accordance with the guidance of SEI/ASCE 7-02. Because the applicant performed its analysis in accordance with the appropriate guidance and the results bound the observations described above, the staff concludes that a 100-year return period snowpack site characteristic value of 30.5 lbf/ft^2 is acceptable.

The applicant has identified a 48-hour PMWP value of 20.75 in. of water for the North Anna ESP site. Because the applicant determined this value in accordance with the guidance of NUREG/CR-1486, "Seasonal Variation of 10-Square-Mile Probable Maximum Precipitation Estimates, United States East of the 105^{th} Meridian," issued April 1980, the staff concludes that a 48-hour PMWP site characteristic value of 20.75 in. of water is acceptable.

Open Item 2.3-2 requests that the applicant justify exclusive use of snowpack weight for calculating snowload or provide an alternative method. In response to Open Item 2.3-2, the applicant has proposed an additional winter precipitation site characteristic. The applicant defined this additional winter precipitation site characteristic as the sum of the 100-year return period snowpack and the 48-hour maximum winter snowfall event. The applicant used the maximum monthly snowfall recorded for Richmond (28.5 in. of snow, which is approximately equivalent to 15 lbf/ft^2) to conservatively define the 48-hour maximum winter snowfall event. The staff has chosen not to include the applicant's proposed sum of the 100-year return period snowpack (30.5 lbf/ft^2) and the 48-hour maximum winter snowfall event (15 lbf/ft^2), 45.5 lbf/ft^2, as an additional winter precipitation site characteristic. Once the roof design is known, the COL or CP applicant has the option to demonstrate that the 48-hour PMWP could neither fall nor remain entirely on top of the 100-year snowpack and/or building roofs.

The following discussion on freezing rain, hail, and lightning is intended to provide a general climatic understanding of the severe weather phenomena in the site region but does not result in the generation of site characteristics for use as design or operating bases.

The NCDC reports a 50-year return period uniform radial ice thickness of 0.75 in. resulting from freezing rain, with a concurrent 3-s gust wind speed of 30 mi/hr for the North Anna ESP site area (Jones, K., et al., "The Development of a U.S. Climatology of Extreme Ice Loads," Technical Report 2002-01).

Hail often accompanies severe thunderstorms. According to the NCDC storm events database (NCDC Storm Event Database, "Storm Events for Virginia, 01/01/1950 through 07/31/2003"), 66 occurrences of hail with diameters of 0.75 in. or greater were reported in the five-county region surrounding the site between January 1, 1955, and July 31, 2003. Seventeen of these occurrences reported hail diameters of 1.5 in. or more. The largest reported size was 2.5 in. which occurred on July 9, 1977, in Caroline County, approximately 25–30 miles southeast of the site. According to NSSL (NCDC, "Severe Thunderstorm Climatology, Total Threat"), the threat of hail occurring within 25 miles of the North Anna ESP site is approximately 2 days per year for damaging hail or hail 0.75 in. in diameter or greater, and 0.25 to 0.50 days per year for hail 2 in. or more in diameter.

The applicant has estimated that approximately 11.2 lightning flashes per year per square mile occur around the site area. The applicant's estimate is consistent with the mean annual ground flash density of 4 flashes per square kilometer (10.4 flashes per square mile) presented in NUREG/CR-3759, "Lightning Strike Density for the Contiguous United States from Thunderstorm Duration Records," issued in 1984 for the North Anna ESP site region.

Large-scale episodes of atmospheric stagnation are not infrequent in the site region. Korshover ("Climatology of Stagnating Anticyclones East of the Rocky Mountains, 1936–1975") reports that, during the 40-year period between 1936 and 1975, high-pressure stagnation conditions, lasting for 4 days or more, occurred about 49 times, with an average of 4.8 stagnation days per case. Five of these stagnation cases lasted 7 days or longer.

The staff found that, according to Holzworth ("Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution throughout the Contiguous United States"), seasonal mixing heights range from an average low of 400 meters (1300 ft) during autumn mornings to an average high of 1800 meters (5900 ft) during spring and summer afternoons. According to Hosler ("Low-Level Inversion Frequency in the Contiguous United States"), low-level, mostly nocturnal inversions are expected to occur approximately 30 percent of the time, with the greatest frequency during the fall and winter (approximately 34 percent of the time and 33 percent of the time, respectively) and with the least frequency during the spring and summer (approximately 28 percent of the time for each season).

The above discussion on atmospheric stagnation, mixing heights, and inversions is intended to provide a general climatic understanding of the air pollution potential in the region. Section 2.3.2 of this SER discusses the ESP air quality conditions considered for design and operating bases. Section 2.3.4 and 2.3.5 of this SER present the atmospheric dispersion site characteristics used to evaluate short-term postaccident airborne releases and long-term routine airborne releases, respectively.

In order to verify the applicant's UHS meteorological site characteristic resulting in minimum water cooling and maximum evaporation and drift loss, the staff examined 30 years (1961–1990) of hourly temperature and humidity data from Richmond ("Solar and Meteorological Surface Observational Network (SAMSON) for Eastern U.S. CDROM"). The staff calculated 1-day, 5-day, and 30-day average wet-bulb temperatures from the hourly data and selected the periods with the highest average wet-bulb temperatures as the worst periods.

The resulting maximum 1-day, 5-day, and 30-day average wet-bulb temperature values were similar to the values presented by the applicant.

In Open Item 2.3-3, the staff identified the need for an additional UHS meteorological site characteristic for use in evaluating the potential for ice formation in the UHS water storage facility. In its response to Open Item 2.3-3, the applicant identified a maximum cumulative degree-days below freezing value of 322 °F degree-days as a UHS meteorological site characteristic for use in evaluating the potential for water freezing in the UHS water storage facility. Section 2.4.7 of this SER describes the staff's independent evaluation of the meteorological conditions resulting in the maximum formation of surface ice (and therefore the minimum initial volume of liquid water available to the UHS). Using daily temperature data from Piedmont, the staff was able to reproduce a maximum cumulative degree-days below freezing value similar to the value presented by the applicant.

Based on the discussion presented above, the staff concludes that the UHS meteorological site characteristics proposed by the applicant are acceptable.

The staff intends to include the regional climatic site characteristics listed in Table 2.3.1-7 in any ESP permit that might be issued for the North Anna ESP site.

Table 2.3.1-7 Staff's Proposed Regional Climatic Site Characteristics

SITE CHARACTERISTIC		VALUE	DESCRIPTION
Ambient Air Temperature and Humidity			
Maximum Dry-Bulb Temperature	2% annual exceedance	90 °F with 75 °F concurrent wet-bulb	The ambient dry-bulb temperature (and coincident wet-bulb temperature) that will be exceeded 2% of the time annually
	0.4% annual exceedance	95 °F with 77 °F concurrent wet-bulb	The ambient dry-bulb temperature (and coincident wet-bulb temperature) that will be exceeded 0.4% of the time annually
	100-year return period	109 °F	The ambient dry-bulb temperature that has a 1% annual probability of being exceeded (100-year mean recurrence interval)
Minimum Dry-Bulb Temperature	99% annual exceedance	18 °F	The ambient dry-bulb temperature below which dry-bulb temperatures will fall 1% of the time annually
	99.6% annual exceedance	14 °F	The ambient dry-bulb temperature below which dry-bulb temperature will fall 0.4% of the time annually
	100-year return period	-19 °F	The ambient dry-bulb temperature for which a 1% annual probability of a lower dry-bulb temperature exists (100-year mean recurrence interval)
Maximum Wet-Bulb Temperature	0.4% annual exceedance	79 °F	The ambient wet-bulb temperature that will be exceeded 0.4% of the time annually
	100-year return period	88 °F	The ambient wet-bulb temperature that has a 1% annual probability of being exceeded (100-year mean recurrence interval)

SITE CHARACTERISTIC	VALUE	DESCRIPTION
Basic Wind Speed		
3-s Gust	96 mi/hr	The 3-s gust wind speed at 33 ft above the ground that has a 1% annual probability of being exceeded (100-year mean recurrence interval)
Tornado		
Maximum Wind Speed	260 mi/hr	Maximum wind speed resulting from passage of a tornado having a probability of occurrence of 10^{-7} per year
Translational Speed	52 mi/hr	Translation component of the maximum tornado wind speed
Rotational Speed	208 mi/hr	Rotation component of the maximum tornado wind speed
Radius of Maximum Rotational Speed	150 ft	Distance from the center of the tornado at which the maximum rotational wind speed occurs
Maximum Pressure Drop	1.5 lbf/in.^{2}	Decrease in ambient pressure from normal atmospheric pressure resulting from passage of the tornado
Maximum Rate of Pressure Drop	0.76 lbf/in.^{2}/s	Rate of pressure drop resulting from the passage of the tornado
Winter Precipitation		
100-Year Snowpack	30.5 lbf/ft^2	Weight of the 100-year return period snowpack (to be used in determining normal precipitation loads for roofs)
48-Hour Probable Maximum Winter Precipitation	20.75 in. of water	Probable maximum precipitation during the winter months (to be used in conjunction with the 100-year snowpack in determining extreme winter precipitation loads for roofs)
Ultimate Heat Sink		
Meteorological Conditions Resulting in the Minimum Water Cooling During Any 1 Day	78.9 °F wet-bulb temperature with coincident 87.7 °F dry-bulb temperature	Historic worst 1-day daily average of wet-bulb temperatures and coincident dry-bulb temperatures
Meteorological Conditions Resulting in the Minimum Water Cooling During Any Consecutive 5 Days	77.6 °F wet-bulb temperature with coincident 80.9 °F dry-bulb temperature	Historic worst 5-day daily average of wet-bulb temperatures and coincident dry-bulb temperatures resulting in minimum water cooling
Meteorological Conditions Resulting in the Maximum Evaporation and Drift Loss During Any Consecutive 30 Days	76.3 °F wet-bulb temperature with coincident 79.5 °F dry-bulb temperature	Historic worst 30-day daily average of wet-bulb temperatures and coincident dry-bulb temperatures
Meteorological Conditions Resulting in Maximum Water Freezing in the UHS Water Storage Facility	322 °F degree-days below freezing	Historic maximum cumulative degree-days below freezing

The staff acknowledges that long-term climatic change resulting from human or natural causes may introduce trends into design conditions. However, no conclusive evidence or consensus of opinion is available on the rapidity or nature of such changes. If in the future the ESP site is no longer in compliance with the terms and conditions of the ESP (e.g., new information shows that the climatic site characteristics no longer represent extreme weather conditions due to climate change), the staff may seek to modify the ESP or impose requirements on the site in accordance with the provisions of 10 CFR 52.39, "Finality of Early Site Permit Determinations," if necessary, to bring the site into compliance with Commission requirements to assure adequate protection of the public health and safety.

2.3.1.4 Conclusions

As set forth above, the applicant has presented and substantiated information relative to the regional meteorological conditions important to the safe design and siting of a nuclear power plant or plants falling within the applicant's PPE that might be constructed on the proposed site. The staff has reviewed the available information provided and, for reasons given above, concludes that the identification and consideration of the regional and site meteorological characteristics set forth above meet the requirements of 10 CFR 100.20(c) and 10 CFR 100.21(d).

The staff finds that the applicant has considered the most severe regional weather phenomena in establishing the site characteristics identified above. The staff has generally accepted the methodologies used to determine the severity of the weather phenomena reflected in these site characteristics, as documented in SERs for previous licensing actions. Accordingly, the staff concludes that the use of these methodologies results in site characteristics containing margin sufficient for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the site characteristics previously identified are acceptable for use as part of the design bases for SSCs important to safety, as may be proposed in a COL or CP application.

With regard to tornado wind speed, the applicant conducted a technical assessment of site-specific tornado data. The staff finds the assessment sufficient to justify the applicant's proposed site tornado characteristics, which deviate from the staff's interim position on design-basis tornado characteristics. In addition, the staff finds that these tornado site characteristics are acceptable for the design-basis tornado used for the generation of missiles.

The staff has reviewed the applicant's proposed site characteristics related to climatology for inclusion in an ESP for the applicant's site, should one be issued, and finds these characteristics to be acceptable. The staff has also reviewed the applicant's proposed design parameters (PPE values) for inclusion in such an ESP (SSAR Section 1.3) and finds them to be reasonable. The staff did not perform a detailed review of these parameters.

2.3.2 Local Meteorology

2.3.2.1 Technical Information in the Application

In Section 2.3.2 of the SSAR, the applicant presented local (site) meteorological information. This SSAR section also addresses the potential influence of construction and operation of a nuclear power plant or plants falling within the applicant's PPE on local meteorological conditions that might in turn adversely impact such a plant or plants or the associated facilities.

Finally, the applicant provided a topographical description of the site and its environs. The applicant presented the following information:

- a description of the local (site) meteorology in terms of airflow, temperature, atmospheric water vapor, precipitation, fog, atmospheric stability, and air quality
- an assessment of the influence on the local meteorology of construction and operation of a nuclear power plant or plants falling within the applicant's PPE that might be constructed on the proposed site and its facilities, including the effects of plant structures, terrain modification, and heat and moisture sources resulting from plant operation
- a topographical description of the site and its environs, as modified by the structures of a nuclear power plant or plants falling within the applicant's PPE that might be constructed on the proposed site

The applicant used data from the NWS first-order weather station at Richmond, Virginia, as well as data provided by NCDC from six nearby cooperative observer weather stations, to characterize temperature, rainfall, and snowfall for the North Anna ESP site area. The applicant also provided wind, humidity, and fog data collected at Richmond.

In general, the applicant considered the more extensive meteorological data available for Richmond to be fairly representative of conditions in the ESP site area. However, the applicant noted slight differences in the Richmond data with respect to minimum temperature extremes, diurnal temperature ranges, and average annual snowfall, as compared to corresponding data observed at nearby cooperative weather stations. The applicant attributed these differences to the consequences of urban heating for the more urban Richmond location.

The applicant also characterized local meteorological conditions using data collected from the meteorological monitoring program at the existing NAPS. According to the applicant, the meteorological variables collected by the NAPS monitoring program are appropriate for use in describing local meteorological conditions because of the proximity of the NAPS meteorological tower to the ESP site.

The applicant presented historical normals (e.g., 30-year averages) and extremes of temperature, rainfall, and snowfall for the seven nearby NWS and cooperative weather stations in the North Anna ESP site area. Daily mean temperatures among the observing stations are fairly similar, ranging from 54.2 °F to 57.6 °F. Extreme maximum temperatures have ranged from 100 °F to 107 °F, whereas extreme minimum temperatures have ranged from -10 °F to -21 °F. Normal annual precipitation totals are also fairly comparable among these observing stations, ranging from 42.24 in. to 48.87 in. Normal annual snowfall totals range from 12.4 in. to 18.8 in.

According to the applicant, an average of 27.2 days per year of heavy fog has been reported for Richmond, which is the location closest to the North Anna ESP site for which a fog data set exists. Low regions at the site and in the vicinity of Lake Anna would be expected to have a higher frequency of fog occurrences because of the accumulation of relatively cool surface air from flows draining from higher elevations, as compared to the relatively flat region of the Richmond weather station.

According to information provided by the applicant, onsite winds occur along a north-south orientation on an annual basis, with seasonal variations. Wind data taken from the 33-ft level of the onsite meteorological tower for the 14-year period between 1974 and 1987 indicate that the predominant wind directions are from the south-southwest (about 10 percent of the time), north (about 9 percent of the time), northwest (about 9 percent of the time), and west-northwest (about 8 percent of the time). Winds from the northeast clockwise through south-southeast and from the west-southwest and the west occur least frequently (each about 4 percent of the time). Wind direction distributions based on data from the 159-ft level are similar to those based on the lower-level data. The onsite annual average wind speeds are 6.3 mi/hr at the 33-ft level and 8.6 mi/hr at the 159-ft level.

The SSAR presents atmospheric stability data based on delta-temperature measurements between the 159-ft and 33-ft levels on the onsite meteorological tower. Neutral (Pasquill type "D") and slightly stable (Pasquill type "E") conditions predominate, occurring about 31 and 26 percent of the time, respectively. Moderately stable (Pasquill type "F") and extremely stable (Pasquill type "G") conditions occur about 8 and 5 percent of the time, respectively.

The applicant stated that the dimensions of the new plant structures and associated paved, concrete, and other improved surfaces would be insufficient to generate discernable impacts on local and regional meteorological conditions beyond the areas immediately adjacent to the site structures and improved surfaces. The applicant concluded that the small and localized surface water temperature increases on Lake Anna resulting from the operation of an open-cycle cooling system for the applicant's proposed Unit 3 would not be expected to significantly impact the ongoing moderation of temperature extremes and alterations of local wind patterns by the lake. Induced fogging conditions under extreme humidity conditions during cooler seasons would most likely coincide with naturally occurring fogging conditions, and the applicant does not expect the proposed Unit 3 to significantly increase the occurrence of local fog. Similarly, the applicant expects that any increases in ambient temperatures resulting from the operation of a closed-loop dry tower system proposed for Unit 4 would be very localized to the ESP site and would not affect the ambient ground and atmospheric temperatures beyond the site boundary.

In Open Item 2.3-4, the staff stated that the applicant has not described the impact of potential increases in atmospheric temperature resulting from the operation of closed-cycle (dry) cooling towers associated with proposed Unit 4 on plant design and operation. In its response to Open Item 2.3-4, the applicant stated that the operation of the dry cooling towers would be expected to have minimal impact on the design and operation of the new Units 3 and 4. The dry cooling towers would be approximately 150 ft high and would consist of a series of modules, each containing air circulating fans. According to the applicant, the warm air plume from the dry cooling towers would tend to rise vertically, driven by the velocity imparted by the fans and thermal buoyancy. During most expected atmospheric conditions, the resulting heated plume would be expected to rise above the top of the tallest powerblock structures in the plant envelope area. Only a strong wind blowing across the bank of cooling towers could cause plume downwash because of building wake effects. This strong wind would also enhance the mixing with cooler air from outside the plume, resulting in negligible changes in temperature at ground level.

Since the specific design of the ESP facility is not known, the applicant stated that it is not possible to predict with certainty the impact of the warm air dry cooling tower plumes on specific plant features, such as heating, ventilation, and air-conditioning intakes. The applicant stated that potential impact of the dry cooling towers on the design and operation on the ESP facility would be considered as part of detailed engineering.

According to the applicant, the North Anna ESP site region is characterized by gently rolling terrain that rises to an average height of 50 to 150 ft above Lake Anna. The primary topographic influences on local meteorological conditions at the North Anna ESP site are Lake Anna and the North Anna River Valley. Because of the complex configuration of the lake, over-water trajectories would generally be less than 2.5 miles. As a result of the gently rolling terrain, cold air drains into low-lying areas at night. Some wind channeling along Lake Anna is expected during low wind speed conditions. The Blue Ridge Mountains, which are located 40 to 50 miles northwest of the site, also tend to channel the prevailing winds from the south and south-southwest during the summer months.

The applicant stated that, should additional units be constructed, a portion of the currently undeveloped area of the ESP site would be cleared of existing vegetation and subsequently graded to accommodate the new units and the ancillary structures. No large-scale cut and fill activities would be needed to accommodate the new units since a large portion of the area to be developed is already relatively level. Therefore, the applicant expects that terrain modifications associated with development of the ESP facility would be limited to the existing NAPS site and would not impact terrain features around the lake and valley nor significantly alter the site's existing gently undulating surface that is characteristic of its location in the Piedmont region of Virginia.

The applicant stated that it did not expect air quality characteristics to be a significant factor in the design and operating bases for any new facilities that might be constructed on the ESP site. The North Anna ESP site is located within the Northeastern Virginia Intrastate Air Quality Control Region, which has been designated as being in attainment or unclassified for all EPA-designated national ambient air quality standards. The nuclear steam supply system and related radiological systems associated with any new facilities that might be constructed on the ESP site would not be sources of criteria pollutants or other air toxics. Further, the applicant does not expect the addition of supporting auxiliary boilers, emergency diesel generators, station blackout generators, and other sources of nonradiological emissions to be significant sources of criteria pollutant emissions because these units will operate on an intermittent test and/or emergency basis.

2.3.2.2 Regulatory Evaluation

In SSAR Section 1.8.1, the applicant identified the following applicable NRC regulations regarding local meteorology:

- Appendix A to 10 CFR Part 50, GDC 2, with respect to information on severe regional weather phenomena that has historically been reported for the region and that is reflected in the design bases for SSCs important to safety
- 10 CFR 100.20(c) and 10 CFR 100.21(d), with respect to the consideration that has been given to the regional meteorological characteristics of the site

In SSAR Section 1.8.2, the applicant identified the following applicable NRC guidance regarding local meteorology:

- RG 1.23, Revision 0, "Onsite Meteorological Programs," dated February 1972 and proposed Revision 1, dated September 1980, with respect to the criteria for an acceptable onsite meteorological measurements program

- Section 2.3.2 of RG 1.70, with respect to the type of local meteorological information that should be presented, including the potential impact of the plant on local meteorology and the local meteorological and air quality conditions used for design and operating basis considerations

The staff has reviewed this portion of the application in accordance with the guidance identified by the applicant, and to determine if the application is in compliance with the identified regulations, with the exception of the GDC. An ESP applicant need not demonstrate compliance with the GDC with respect to local meteorology.

Section 2.3.2 of RS-002 and Section 2.3.2 of RG 1.70 provide the following guidance on information appropriate for presentation on local meteorology:

- Local meteorological data based on onsite measurements and data from nearby NWS stations or other standard installations should be presented in the format specified in Section 2.3.2 of RG 1.70. RG 1.23 provides guidance related to onsite meteorological measurements.

- A topographical description of the site and environs should be provided. Section 2.3.2.2 of RG 1.70 provides guidance on the topographical description.

- A discussion and evaluation of the influence of a nuclear power plant or plants of specified type (or falling within a PPE) that might be constructed on the proposed site and its facilities on local meteorological and air quality conditions should be provided. Potential changes in the normal and extreme values resulting from plant construction and operation should be discussed.

2.3.2.3 Technical Evaluation

The staff evaluated local meteorological conditions using data from the NAPS onsite meteorological monitoring system, as well as climatic data reported by NCDC. Section 2.3.3 of this SER provides a discussion of the representativeness of the NAPS onsite data.

Normal climatic data for the period 1971–2000 reported by NCDC for the eastern Piedmont climatic division of Virginia indicate that the annual mean temperature in the area is about 56.6 °F (NCDC, "Eastern Piedmont, Virginia, Divisional Normals—Temperature, Period 1971–2000, Climatography of the United States No. 85"). This value compares well with the range of daily mean temperatures reported by the applicant for nearby weather stations. Monthly mean temperatures for the eastern Piedmont climatic division range from a low monthly mean value of about 35.9 °F in January to a high monthly mean value of about 76.8 °F in July (NCDC, "Eastern Piedmont, Virginia, Divisional Normals—Temperature, Period 1971–2000, Climatography of the United States No. 85").

Precipitation for the Piedmont climatic division averages 45.00 in. per year (NCDC, "Eastern Piedmont, Virginia, Divisional Normals—Precipitation, Period 1971–2000, Climatography of the United States No. 85"). This value is compatible with the range of normal annual precipitation totals reported by the applicant for nearby weather stations. Precipitation is well distributed throughout the year, with monthly climate division normals for the North Anna ESP site region ranging from a minimum of about 3.18 in. in December to a maximum of about 4.36 in. in July.

The staff reviewed the applicant's description of the local meteorology and determined that the information is representative of conditions at and near the site. The wind and atmospheric stability data are based on onsite data recorded by the NAPS meteorological monitoring system. Section 2.3.3 of this SER provides a discussion of the NAPS onsite data. The other meteorological summaries are based on data from nearby stations with long periods of record. The applicant demonstrated that synoptic-scale conditions are generally responsible for periods of excessive heat and cold outbreaks that resulted in the recording of compatible extreme temperatures throughout the ESP site area. A review of these recorded extreme values shows that they are reflected in the site characteristics presented in SSAR Section 2.3.1.

The staff reviewed topographic maps and topographic cross sections to ensure that the information needed is well labeled and can be readily extracted.

Because of the limited and localized nature of the expected terrain modifications associated with the development of the ESP facility, the staff finds that these terrain modifications, along with the resulting plant structures and associated improved surfaces, will not have enough of an effect on local meteorological conditions to affect plant design and operation. Similarly, because the operation of an open-cycle cooling system for the applicant's proposed Unit 3 is not expected to significantly impact either atmospheric temperature extremes or increase the occurrence of local fog, the staff finds that the atmospheric impact of the operation of an open-cycle cooling system for the proposed Unit 3 will not affect plant design and operation.

In Open Item 2.3-4, the staff requested that the applicant describe the impact of potential increases in atmospheric temperature resulting from the operation of closed-cycle dry cooling tower and associated with proposed Unit 4 on plant design and operations. In its response to Open Item 2.3-4, the applicant noted that it is not possible to predict with certainty the warm air transport and dispersion from the cooling tower to specific plant features because the design of the plant is not known at this time.

Since the specific layout and design of the ESP facility is not known, the staff finds that it is not possible to accurately predict the impact of the Unit 4 dry cooling tower plumes on specific plant features. The potential impact of the dry cooling towers on the design and operation of the ESP facility should be considered as part of detailed engineering and will need further evaluation at the time of the COL application. This is **COL Action Item 2.3-1**.

Since the North Anna ESP site is located in an air quality control region that has been designated as being either in attainment or unclassifiable for all EPA-designated national ambient air quality standards, the staff agrees with the applicant that the ESP site air quality conditions should not be a significant factor in the design and operating bases for the new units.

2.3.2.4 Conclusions

As set forth above, the applicant has presented and substantiated information on local meteorological, air quality, and topographic characteristics of importance to the safe design and operation of a nuclear power plant or plants falling within the applicant's PPE that might be constructed on the proposed site. The staff has reviewed the available information provided and, for the reasons given, concludes that the applicant's identification and consideration of the meteorological, air quality, and topographical characteristics of the site and the surrounding area meet the requirements of 10 CFR Part 100, 10 CFR 100.20(c), and 10 CFR 100.21(d) and are sufficient to determine the acceptability of the site.

The staff has also reviewed available information relative to severe local weather phenomena at the site and in the surrounding area. As set forth above, the staff concludes that the applicant has identified the most severe local weather phenomena at the site and surrounding area.

2.3.3 Onsite Meteorological Measurements Program

2.3.3.1 Technical Information in the Application

In Section 2.3.3 of the SSAR, the applicant presented information concerning its Onsite Meteorological Measurements Program, including instrumentation and measured data. Specifically, the applicant provided the following information:

- description of meteorological instrumentation, including siting of sensors, sensor performance specifications, methods and equipment for recording sensor output, the quality assurance program for sensors and recorders, and data acquisition and reduction procedures

- meteorological data, including consideration of the period of record and amenability of the data for use in characterizing atmospheric dispersion conditions

The applicant used the existing Onsite Meteorological Measurements Program for the NAPS facility to collect data for the North Anna ESP site and intends to use it for the proposed ESP facility.

The applicant upgraded the existing NAPS monitoring program in June 1977, and, according to the applicant, it meets the system accuracy criteria presented in proposed Revision 1 to RG 1.23. Measurements are available from both a primary and backup system. The backup system is intended to function when the primary system is out of service, providing assurance that basic meteorological information will be available during and immediately following an accidental airborne radioactivity release.

The primary NAPS meteorological monitoring program consists of a guyed, triaxial, open-lattice 160-ft tower located approximately 1900 ft east of the NAPS Unit 1 reactor containment building. Wind speed, wind direction, and horizontal wind direction fluctuation (sigma theta) are measured at the 33-ft and 159-ft elevations. Ambient temperature and dew point temperature are measured at the 33-ft elevation, and vertical temperature difference (delta-temperature) is measured between the 160-ft and 33-ft elevations. Precipitation is monitored at the ground level.

The backup NAPS meteorological monitoring program consists of a freestanding 33-ft tower located approximately 1300 ft northeast of the NAPS Unit 1 reactor containment building. Wind speed, wind direction, and horizontal wind direction fluctuation (sigma theta) are measured at the top of the tower. The bases of both towers are at similar elevation to plant grade, and the ground cover at the base of the primary tower (which measures delta-temperature) is primarily native grasses.

Signal cables from both the primary and backup towers are routed through conduit into an instrument shelter at the base of each tower. Inside each shelter, the signals are provided as input to the appropriate signal-conditioning equipment, with output going to digital data recorders. These data are transmitted daily via modem to the applicant's corporate headquarters, where they are reviewed to identify anomalous data and then archived. Output from the signal-conditioning equipment is also sent to strip chart recorders in the control room and the emergency response facility data system for use in emergency response.

The primary tower wind sensors are mounted on booms approximately twice the tower face width and are positioned so that the tower will not influence the prevailing south-southwest wind flow. The ambient temperature, dew point temperature, and delta-temperature sensors are housed in motor-aspirated shields to insulate them from the effects of precipitation and thermal radiation.

The meteorological monitoring system is calibrated at least semiannually. Data recovery for the 1996–1998 period of record used to evaluate atmospheric dispersion exceeded 90 percent.

2.3.3.2 Regulatory Evaluation

In SSAR Section 1.8.1, the applicant identified the following applicable NRC regulations regarding the Onsite Meteorological Measurements Program:

- 10 CFR 50.47, "Emergency Plans," and Appendix E, "Emergency Planning and Preparedness for Production and Utilization Facilities," to 10 CFR Part 50, as they relate to additional meteorological measurements taken for emergency preparedness planning
- Appendix I to 10 CFR Part 50, as it relates to meteorological data used to determine compliance with the numerical guides for doses in meeting the criterion of "as low as is reasonably achievable"
- 10 CFR 100.20(c) and 10 CFR 100.21(d), as they relate to meteorological data collected for use in characterizing the meteorological conditions of the site

In SSAR Sections 1.8.2 and 2.3.3, the applicant identified the following applicable NRC guidance regarding onsite meteorological measurements programs:

- RG 1.23, Revision 0, and proposed Revision 1, with respect to the criteria for an acceptable onsite meteorological measurements program

- Section 2.3.3 of RG 1.70, with respect to describing the meteorological measurements at the site and providing joint frequency distributions of wind speed and direction by atmospheric stability class

- Section 2.3 of RG 4.2, "Preparation of Environmental Reports for Nuclear Power Stations," issued July 1976, with respect to providing at least one annual cycle of onsite meteorological data

- Appendix 2 to NUREG-0654, Revision 1, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," issued November 1980; NUREG-0696, "Functional Criteria for Emergency Response Facilities," issued February 1981; and NUREG-0737, "Clarification of TMI Action Plan Requirements," issued October 1980, with respect to meteorological measurements taken for emergency preparedness planning

The staff has reviewed this portion of the application in accordance with the guidance identified by the applicant, and to determine if the application is in compliance with the identified regulations. However, this section of the application did not address the requirements of 10 CFR 50.47 and Appendix E to 10 CFR Part 50. Consequently, the staff did not review this section for compliance with these requirements.

Both RG 1.23 and Section 2.3.3 of RS-002 document the criteria for an acceptable onsite meteorological measurements program. The onsite meteorological measurements program should produce data that describe the meteorological characteristics of the site and its vicinity for the purpose of making atmospheric dispersion estimates for both postulated accidental and expected routine airborne releases of effluents, and for comparison with offsite sources to determine the appropriateness of climatological data used for design considerations.

Section 2.3.3 of RS-002 and Section 2.3.3.7 of RG 1.70 provide guidance on information appropriate for presentation on an onsite meteorological measurements program. As set forth in this guidance, at least one annual cycle of onsite meteorological data should be provided. These data should be presented in the form of joint frequency distributions of wind speed and wind direction by atmospheric stability class in the format described in RG 1.23. If a site has a high occurrence of low wind speeds, a finer category breakdown should be used for the lower speeds so data are not clustered in a few categories. A listing of each hour of the hourly averaged data should also be provided on electronic media in the format described in Appendix A to Section 2.3.3 of RS-002. Evidence of how well these data represent long-term conditions at the site should be discussed.

2.3.3.3 Technical Evaluation

The staff evaluated the Onsite Meteorological Measurements Program by reviewing the program description presented in the SSAR, as well as conducting a site visit. The site visit consisted of reviewing the meteorological monitoring system location and exposure, sensor type and performance specifications, data transmission and recording, data acquisition and reduction, and instrumentation maintenance and calibration procedures. In addition, the staff reviewed an hourly listing of the 1996–1998 meteorological database provided by the applicant in its response to RAI 2.3.3-1.

The staff considers the meteorological data collected by the existing NAPS monitoring program to be representative of the dispersion conditions at the North Anna ESP site. The North Anna ESP site is within the existing NAPS site, and the proposed facility is intended to be in close proximity to the existing facility. The NAPS primary meteorological tower is located far enough away from existing plant structures to preclude any adverse impact on measurements. The base of the tower is at an elevation similar to plant grade at both NAPS and the proposed ESP facility. The ground cover at the base of the meteorological tower is primarily native grasses.

The staff reviewed the location of the primary and backup towers with respect to nearby ground features and potential obstructions to flow (e.g., trees, buildings), including existing plant structure layouts, and concluded that these features pose minimal adverse effects on the measurements taken at the towers. The nearby instrument shelters for both towers are less than 10 ft in height. Pine trees, previously 30–35 ft in height and located approximately 135 ft northwest and south of the primary tower, were cut in 2002 to 23–27 ft in height. Dominion Energy has put these trees on a 3-year pruning schedule to ensure they remain below 30 ft in height (i.e., below the lower measuring height on the primary tower), as recommended in proposed Revision 1 to RG 1.23.

The staff evaluated the types and heights of the meteorological variables being measured and found them to be compatible with the criteria of RG 1.23. During the site visit, the staff also reviewed the applicant's sensor types and performance specifications, data transmission and recording methods, and the inspection, maintenance, and calibration procedures and frequencies. The staff found them to be consistent with RG 1.23.

The staff performed a quality review of the NAPS 1996–1998 hourly meteorological database provided by the applicant in response to RAI 2.3.3-1 using the methodology described in NUREG-0917, "Nuclear Regulatory Commission Staff Computer Programs for Use with Meteorological Data," issued July 1982. The staff performed further review using computer spreadsheets. Examination of the data revealed generally stable and neutral atmospheric conditions at night and unstable and neutral conditions during the day, as expected. Wind speed, wind direction, and stability class frequency distributions for each measurement channel were similar from year to year, and the 1996–1998 wind direction and stability class frequency distributions were reasonably consistent with the 1974–1987 data presented in Section 2.3.2 of the NAPS UFSAR. A comparison between the joint frequency distribution used by the licensee as input to PAVAN and XOQDOQ and a staff-generated joint frequency distribution from the hourly database are compatible.

2.3.3.4 Conclusions

As set forth above, the applicant has provided and substantiated information on the Onsite Meteorological Measurements Program. The staff has reviewed the available information relative to the meteorological measurements program and the data collected by the program. On the basis of this review and as set forth above, the staff concludes that the system provides data adequate to represent onsite meteorological conditions, as required by 10 CFR 100.20. The onsite data also provide an acceptable basis for (1) making estimates of atmospheric dispersion for design-basis accident and routine releases from a nuclear power plant or plants falling within the applicant's PPE that might be constructed on the proposed site and (2) meeting the requirements of 10 CFR Part 100 and Appendix I to 10 CFR Part 50.

2.3.4 Short-Term (Accident) Diffusion Estimates

2.3.4.1 Technical Information in the Application

In this section of the SSAR, the applicant presented atmospheric dispersion estimates for postulated accidental airborne releases of radioactive effluents to the EAB and LPZ. The applicant provided the following information:

- atmospheric transport and diffusion models to calculate relative concentrations for postulated accidental radioactive releases
- meteorological data summaries used as input to diffusion models
- specification of diffusion parameters
- probability distributions of relative concentrations
- determination of relative concentrations used for assessment of consequences of postulated radioactive atmospheric releases from design-basis and other accidents

The applicant used the NRC-sponsored computer code PAVAN (NUREG/CR-2858, "PAVAN: An Atmospheric Dispersion Program for Evaluating Design Basis Accidental Releases of Radioactive Materials from Nuclear Power Stations," issued in 1982) to estimate relative concentration (χ/Q) values at the EAB and LPZ for potential accidental releases of radioactive material. The PAVAN model implements the methodology outlined in RG 1.145, Revision 1, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," issued November 1982.

The PAVAN code estimates χ/Q values for various time-averaging periods ranging from 2 hours to 30 days. The meteorological input to PAVAN consists of a joint frequency distribution of wind speed, wind direction, and atmospheric stability data. The PAVAN code computes χ/Q values at the EAB and LPZ for each combination of wind speed and atmospheric stability for each of the 16 downwind direction sectors. The code then ranks χ/Q values for each sector in descending order, and it derives an associated cumulative frequency distribution based on the frequency distribution of wind speed and stabilities for that sector. The χ/Q value that is equaled or exceeded 0.5 percent of the total time is determined for each sector, and the highest 0.5-percentile χ/Q value among the 16 sectors becomes the maximum sector-dependent χ/Q value. The code also ranks χ/Q values independent of wind direction into a cumulative frequency distribution for the entire site. The PAVAN program then selects the χ/Q value that is equaled or exceeded 5 percent of the total time. The larger of the two values, the maximum sector-dependent 0.5-percent χ/Q value and the overall site 5-percent χ/Q value, are used to represent the χ/Q value for a 0–2-hour time period.

To determine χ/Q values for longer time periods, PAVAN calculates an annual average χ/Q value. Logarithmic interpolation is then used between the 0–2-hour χ/Q values and the annual average χ/Q values to calculate the values for intermediate time periods (i.e., 8 hours, 16 hours, 72 hours, and 624 hours).

In RAI 2.3.4-1, the staff asked the applicant to rerun the PAVAN computer code using the wind speed categories discussed in Section 4.6 of NUREG/CR-2858 and provide a copy of the resulting input files used to execute PAVAN. The applicant complied with this request in its response to RAI 2.3.4-1.

The applicant used the following input data and assumptions in applying the PAVAN model for the North Anna site:

- The meteorological input to PAVAN consisted of a joint frequency distribution of wind speed, wind direction, and atmospheric stability data based on 3 years (1996–1998) of onsite meteorological data. The applicant used wind data from the 33-ft level of the onsite meteorological tower, and it derived the stability data from the vertical temperature difference (delta-temperature) measurements taken between the 159-ft and 33-ft levels of the onsite meteorological tower.

- The applicant modeled one conservative ground-level release point and took no credit for building wake effects.

- The EAB is the perimeter of a 5000-ft radius circle from the center of the abandoned Unit 3 containment. In order to calculate the χ/Q values for the EAB, the applicant used the shortest distances from the ESP plant envelope area boundary to the EAB. The LPZ is a 6-mi-radius circle centered at the Unit 1 containment building. Similarly, in order to calculate the χ/Q values for the LPZ, the applicant used the shortest distances from the ESP plant envelope area boundary to the LPZ.

Based on the PAVAN modeling results, the applicant proposed short-term (accident release) atmospheric dispersion site characteristics for inclusion in an ESP, as presented in Table 2.3.4-1, should one be issued for the applicant's proposed ESP site.

Table 2.3.4-1 Applicant's Proposed Short-Term (Accident Release) Atmospheric Dispersion Site Characteristics

SITE CHARACTERISTIC	VALUE	DEFINITION
0–2 hr χ/Q Value @ EAB	2.26×10^{-4} s/m^3	The atmospheric dispersion factor used in the safety analysis to estimate dose consequences of accidental airborne releases
0–8 hr χ/Q Value @ LPZ	2.05×10^{-5} s/m^3	The atmospheric dispersion factor used in the safety analysis to estimate dose consequences of accidental airborne releases
8–24 hr χ/Q Value @ LPZ	1.36×10^{-5} s/m^3	The atmospheric dispersion factor used in the safety analysis to estimate dose consequences of accidental airborne releases
1–4 day χ/Q Value @ LPZ	5.58×10^{-6} s/m^3	The atmospheric dispersion factor used in the safety analysis to estimate dose consequences of accidental airborne releases
4–30 day χ/Q Value @ LPZ	1.55×10^{-6} s/m^3	The atmospheric dispersion factor used in the safety analysis to estimate dose consequences of accidental airborne releases

2.3.4.2 Regulatory Evaluation

In SSAR Section 1.8.1, the applicant identified the applicable NRC regulation regarding short-term (accident release) diffusion estimates as 10 CFR 100.21, with respect to the meteorological considerations used in the evaluation to determine an acceptable exclusion area and LPZ.

In SSAR Sections 1.8.2 and 2.3.4, the applicant identified the following applicable NRC guidance regarding accident release diffusion estimates:

- RG 1.5, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Steam Line Break Accident for Boiling Water Reactors," issued March 1971; RG 1.24, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Pressurized Water Reactor Radioactive Gas Storage Tank Failure," issued March 1972; RG 1.25, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors," issued March 1972; RG 1.77, "Assumptions Used for Evaluating a Control Rod Ejection Accident for Pressurized Water Reactors," issued May 1974; and RG 1.78, Revision 1, with respect to an acceptable basis for implementing the requirements of 10 CFR Part 100

- RG 1.23, Revision 0, and proposed Revision 1, with respect to the criteria for an acceptable onsite meteorological measurements program

- Section 2.3.4 of RG 1.70, with respect to providing conservative and realistic estimates of atmospheric diffusion at the EAB and LPZ, based on the most representative meteorological data and impacts caused by local topography

- RG 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors," issued July 1977, with respect to criteria for characterizing atmospheric transport and diffusion conditions for evaluating the consequences of routine releases

- RG 1.145, Revision 1, with respect to acceptable methods for choosing atmospheric dispersion factors (χ/Q values) for evaluating the consequences of potential accidents

- RG 4.7, with respect to discussing the major site characteristics related to public health and safety that the staff considers in determining the suitability of the site

The staff has reviewed this portion of the application in accordance with the guidance identified by the applicant, and to determine if the application is in compliance with the identified regulations.

Section 2.3.4 of RS-002 and Section 2.3.4 of RG 1.70 provide guidance on information appropriate for presentation on short-term (accident release) diffusion estimates. The application should present or describe the following:

- conservative estimates of atmospheric transport and diffusion conditions at appropriate distances from the source for postulated accidental releases of radioactive materials to the atmosphere

- a description of the atmospheric dispersion models used to calculate relative concentrations (χ/Q values) in air resulting from accidental releases of radioactive material to the atmosphere, with models documented in detail and substantiated within the limits of the model so that the staff can evaluate their appropriateness to site characteristics, plant characteristics (to the extent known), and release characteristics

- the meteorological data used for the evaluation (as input to the dispersion models), which represent annual cycles of hourly values of wind direction, wind speed, and atmospheric stability for each mode of accidental release

- an explanation of the variation of atmospheric diffusion parameters used to characterize lateral and vertical plume spread (σ_y and σ_z) as a function of distance, topography, and atmospheric conditions, as related to measured meteorological parameters, and description of a methodology for establishing these relationships that is appropriate for estimating the consequences of accidents within the range of distances that are of interest with respect to site characteristics and established regulatory criteria

- cumulative probability distributions of relative concentrations (χ/Q values) and the probabilities of these χ/Q values being exceeded, presented for appropriate distances (e.g., the EAB and LPZ) and time periods as specified in Section 2.3.4.2 of RG 1.70, as well as an adequate description of the methods used for generating these distributions

- the relative concentrations used for assessing the consequences of atmospheric radioactive releases from design-basis and other accidents

2.3.4.3 Technical Evaluation

The applicant generated its atmospheric diffusion estimates for postulated accidental airborne releases of radioactive effluents to the EAB and LPZ using the staff-endorsed computer code PAVAN. The staff evaluated the applicability of the PAVAN model and concluded that no unique topographic features preclude the use of the PAVAN model for the North Anna ESP site. The staff also reviewed the applicant's input to the PAVAN computer code, including the assumptions used concerning plant configuration and release characteristics and the appropriateness of the meteorological data input. The staff found that the applicant made conservative assumptions by ignoring building wake effects and treating all releases as ground-level releases. The staff made an independent evaluation of the resulting atmospheric diffusion estimates by running the PAVAN computer model and obtained similar results.

From this review, the staff concludes that the applicant has used an adequately conservative atmospheric dispersion model and appropriate meteorological data to calculate relative concentrations for appropriate offsite (EAB and LPZ) distances and directions from postulated release points for accidental airborne releases of radioactive materials.

In order to evaluate atmospheric dispersion characteristics with respect to radiological releases to the control room, detailed design information (e.g., vent heights, intake heights, and distance and direction from release vents to the room) is necessary. Because little detailed design information is available for the nuclear power plant or plants that might be constructed on the proposed site, the COL or CP applicant should assess the dispersion of airborne radioactive materials to the control room at the COL or CP stage. This is **COL Action Item 2.3-2.**

The staff intends to include the short-term (accident release) atmospheric dispersion factors listed in Table 2.3.4-2 as site characteristics in any ESP that might be issued for the North Anna ESP site.

Table 2.3.4-2 Staff's Proposed Short-Term (Accident Release) Atmospheric Dispersion Site Characteristics

SITE CHARACTERISTIC	VALUE	DEFINITION
0–2-hr χ/Q Value @ EAB	2.26×10^{-4} s/m^3	The 0–2-hour atmospheric dispersion factor to be used to estimate dose consequences of accidental airborne releases at the EAB
0–8-hr χ/Q Value @ LPZ	2.05×10^{-5} s/m^3	The 0–8-hour atmospheric dispersion factor to be used to estimate dose consequences of accidental airborne releases at the LPZ
8–24-hr χ/Q Value @ LPZ	1.36×10^{-5} s/m^3	The 8–24-hour atmospheric dispersion factor to be used to estimate dose consequences of accidental airborne releases at the LPZ
1–4-day χ/Q Value @ LPZ	5.58×10^{-6} s/m^3	The 1–4-day atmospheric dispersion factor to be used to estimate dose consequences of accidental airborne releases at the LPZ
4–30-day χ/Q Value @ LPZ	1.55×10^{-6} s/m^3	The 4–30-day atmospheric dispersion factor to be used to estimate dose consequences of accidental airborne releases at the LPZ

2.3.4.4 Conclusions

As set forth above, the applicant has made conservative assessments of postaccident atmospheric dispersion conditions using its meteorological data and appropriate diffusion models. The applicant has calculated representative atmospheric transport and diffusion conditions for the EAB and the LPZ. The staff has reviewed the applicant's proposed short-term atmospheric dispersion site characteristics for inclusion in an ESP for the applicant's site, should one be issued, and, as discussed above, finds these characteristics to be acceptable. Therefore, the staff concludes that the applicant's atmospheric dispersion estimates are appropriate for the assessment of consequences from radioactive releases for postulated (i.e., design-basis) accidents, in accordance with 10 CFR 100.21.

Based on these considerations, the staff concludes that the applicant's short-term atmospheric dispersion estimates are acceptable and meet the relevant requirements of 10 CFR Part 100. The staff will address atmospheric dispersion estimates used to evaluate radiological doses for the control room in its review of any COL or CP application that references this information.

2.3.5 Long-Term (Routine) Diffusion Estimates

2.3.5.1 Technical Information in the Application

In this section of the SSAR, the applicant presented its atmospheric diffusion estimates for routine releases of effluents to the atmosphere. Specifically, the applicant provided the following information:

- the atmospheric dispersion models used to calculate concentrations in air and the amount of material deposited as a result of routine releases of radioactive material to the atmosphere

- the meteorological data used as input to diffusion models

- diffusion parameters

- relative concentration (χ/Q) and relative deposition (D/Q) values used to assess the consequences of routine airborne radioactive releases

- points of routine release of radioactive material to the atmosphere, the characteristics of each release mode, and the location of potential receptors for dose computations

The applicant used the NRC-sponsored computer code XOQDOQ (NUREG/CR-2919, "XOQDOQ: Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations," issued in 1982) to estimate χ/Q and D/Q values resulting from routine releases. The XOQDOQ model implements the methodology outlined in RG 1.111. The applicant used the following input data and assumptions in applying the XOQDOQ model for the North Anna ESP site:

- The meteorological input to XOQDOQ consisted of a joint frequency distribution of wind speed, wind direction, and atmospheric stability data based on 3 years (1996–1998) of onsite meteorological data. The wind data were from the 33-ft level of the onsite meteorological tower, and the stability data were derived from the vertical temperature difference (delta-temperature) measurements taken between the 159-ft and 33-ft levels of the onsite meteorological tower.

- The applicant modeled one conservative ground-level release point, assuming a minimum building cross-sectional area of 24,220 square ft.

- Because the PPE area proposed for the North Anna ESP site is an area, not a point, the applicant used the shortest distances from any point on the plant envelope to the receptors of interest as input to the XOQDOQ model.

The applicant calculated annual average undepleted/no decay, undepleted/2.26-day decay, and depleted/8.00-day decay χ/Q values and D/Q values for the site boundary and special receptors of interest (nearest resident, meat animal, and vegetable garden within 5 miles in each downwind sector), as identified in the North Anna Power Station 2001 Radiological Environmental Monitoring Program Annual Report.

Table 2.3.5-1 lists the long-term atmospheric dispersion estimates that the applicant derived based on the XOQDOQ modeling results.

Table 2.3.5-1 Applicant's Long-Term (Routine Release) Diffusion Estimates

TYPE OF LOCATION	X/Q VALUE (s/m^3) UNDEPLETED NO DECAY	UNDEPLETED 2.26-DAY DECAY	DEPLETED 8.00-DAY DECAY	D/Q VALUE (1/m^2)
EAB	3.7×10^{-6} (0.88 mi ESE)	3.7×10^{-6} (0.88 mi ESE)	3.3×10^{-6} (0.88 mi ESE)	1.2×10^{-8} (0.62 mi S)
Residence	2.4×10^{-6} (0.96 mi NNE)	2.4×10^{-6} (0.96 mi NNE)	2.1×10^{-6} (0.96 mi NNE)	7.2×10^{-9} (0.96 mi NNE)
Meat Animal	1.4×10^{-6} (1.37 mi SE)	1.4×10^{-6} (1.37 mi SE)	1.2×10^{-6} (1.37 mi SE)	3.1×10^{-9} (1.56 mi NNE)
Vegetable Garden	2.0×10^{-6} (0.94 mi NE)	2.0×10^{-6} (0.94 mi NE)	1.8×10^{-6} (0.94 mi NE)	6.0×10^{-9} (0.94 mi NE)

2.3.5.2 Regulatory Evaluation

In SSAR Section 1.8.1, the applicant identified the applicable NRC regulations regarding long-term (routine release) diffusion estimates as Appendix I to 10 CFR Part 50, with respect to demonstrating compliance with the numerical guides for doses contained in this appendix by characterizing atmospheric transport and diffusion conditions in order to estimate the radiological consequences of routine releases of materials to the atmosphere.

The staff finds that the applicant should have also identified 10 CFR 100.21(c)(1), which requires that site atmospheric dispersion characteristics be evaluated and dispersion parameters established such that radiological effluent release limits associated with normal operation from the type of facility proposed to be located at the site can be met for any individual located offsite. Nonetheless, for the reasons set forth below, the staff finds that the applicant has met these regulatory requirements.

In SSAR Sections 1.8.2 and 2.3.5, the applicant identified the following applicable NRC guidance regarding routine release diffusion estimates:

- Section 2.3.5 of RG 1.70, with respect to providing realistic estimates of annual average atmospheric transport and diffusion characteristics to a distance of 50 miles from the plant, including a detailed description of the model used and a calculation of the maximum annual average atmospheric dispersion factor (χ/Q value) at or beyond the site boundary for each venting location
- RG 1.111, with respect to criteria for characterizing atmospheric transport and diffusion conditions for evaluating the consequences of routine releases

The staff also identified the following RGs as applicable NRC guidance regarding routine release diffusion estimates:

- RG 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," issued October 1977, with respect to the criteria to be used for specific receptors of interest (applicable to the extent the applicant provides receptors of interest at the ESP stage)

- RG 1.112, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors," issued May 1977, with respect to the criteria to be used to identify release points and release characteristics (applicable to the extent the applicant provides release points and release characteristics at the ESP stage)

As discussed below, the staff finds that the applicant has met the criteria in all applicable RGs for performing routine release diffusion estimates.

Section 2.3.5 of RS-002 and Section 2.3.5 of RG 1.70 provide the following guidance on information appropriate for presentation on long-term (routine release) diffusion estimates.

- The applicant should provide a description of the atmospheric dispersion models used to calculate concentrations in air and the amount of material deposited as a result of routine releases of radioactive material to the atmosphere. The models should be sufficiently documented and substantiated to allow a review of their appropriateness for site characteristics, plant characteristics (to the extent known), and release characteristics.

- The applicant should discuss the relationship between atmospheric diffusion parameters, such as vertical plume spread (σ_z), and measured meteorological parameters. The applicant should substantiate the use of these parameters in terms of the appropriateness of their use in estimating the consequences of routine releases from the site boundary to a radius of 50 miles from the plant site.

- The applicant should provide the meteorological data used as input to the dispersion models. Data used for this evaluation should represent hourly average values of wind speed, wind direction, and atmospheric stability, which are appropriate for each mode of release. The data should reflect atmospheric transport and diffusion conditions in the vicinity of the site throughout the course of a year.

- The applicant should provide the relative concentration (χ/Q) and relative deposition (D/Q) values used for assessing the consequences of routine radioactive gas releases, as described in Section 2.3.5.2 of RG 1.70.

- The applicant should identify points of routine release of radioactive material to the atmosphere, the characteristics of each release mode, and the location of potential receptors for dose computations (if available at the ESP stage). Bounding values for these parameters may be provided at the ESP stage. In such a case, the applicant will need to confirm, at the COL or CP stage, that the parameters provided at the ESP stage bound the actual values provided at the COL or CP stage, and that the calculational methodology used for the confirmation is consistent with that employed at the ESP stage.

2.3.5.3 Technical Evaluation

The applicant generated its atmospheric diffusion estimates for routine airborne releases of radioactive effluents to the site boundary and special receptors of interest using the staff-endorsed computer code XOQDOQ. The staff evaluated the applicability of the XOQDOQ model and concluded that no unique topographic features preclude the use of the XOQDOQ model for the North Anna ESP site. The staff also reviewed the applicant's input to the XOQDOQ computer code, including the assumptions it used concerning plant configuration and release characteristics and the appropriateness of the meteorological data input. The staff found that the applicant made conservative assumptions by treating all releases as ground-level releases. The staff made an independent evaluation of the resulting atmospheric diffusion estimates by running the XOQDOQ computer model and obtaining similar results.

From this review, the staff concludes that the applicant used an appropriate atmospheric dispersion model and adequate meteorological data to calculate relative concentration and relative deposition at appropriate distances from postulated release points for the evaluation of routine airborne releases of radioactive material. Any COL or CP applicant referencing this information should verify that the specific release point characteristics (e.g., release height and building wake dimensions) and specific locations of receptors of interest (e.g., nearest resident or garden) used to generate the ESP long-term (routine release) atmospheric dispersion site characteristics bound the actual values provided at the COL or CP stage. This is **COL Action Item 2.3-3.**

The staff intends to include the long-term (routine release) atmospheric dispersion factors listed in Table 2.3.5-2 as site characteristics in any ESP that the NRC might issue for the North Anna ESP site.

Table 2.3.5-2 Staff's Proposed Long-Term (Routine Release) Atmospheric Dispersion Site Characteristics

SITE CHARACTERISTIC	VALUE	DEFINITION
Annual Average Undepleted/No Decay χ/Q Value @ EAB	3.7×10^{-6} s/m^3	The maximum annual average EAB undepleted/no decay χ/Q value for use in determining gaseous pathway doses to the maximally exposed individual
Annual Average Undepleted/2.26-Day Decay χ/Q Value @ EAB	3.7×10^{-6} s/m^3	The maximum annual average EAB undepleted/2.26-day decay χ/Q value for use in determining gaseous pathway doses to the maximally exposed individual
Annual Average Depleted/8.00-Day Decay χ/Q Value @ EAB	3.3×10^{-6} s/m^3	The maximum annual average EAB depleted/8.00-day decay χ/Q value for use in determining gaseous pathway doses to the maximally exposed individual
Annual Average D/Q Value @ EAB	1.2×10^{-8} 1/m^2	The maximum annual average EAB D/Q value for use in determining gaseous pathway doses to the maximally exposed individual
Annual Average Undepleted/No Decay χ/Q Value @ Nearest Resident ·	2.4×10^{-6} s/m^3	The maximum annual average resident undepleted/no decay χ/Q value for use in determining gaseous pathway doses to the maximally exposed individual
Annual Average Undepleted/2.26-Day Decay χ/Q Value @ Nearest Resident	2.4×10^{-6} s/m^3	The maximum annual average resident undepleted/2.26-day decay χ/Q value for use in determining gaseous pathway doses to the maximally exposed individual
Annual Average Depleted/8.00-Day Decay χ/Q Value @ Nearest Resident	2.1×10^{-6} s/m^3	The maximum annual average resident depleted/8.00-day decay χ/Q value for use in determining gaseous pathway doses to the maximally exposed individual
Annual Average D/Q Value @ Nearest Resident	7.2×10^{-9} 1/m^2	The maximum annual average resident D/Q value for use in determining gaseous pathway doses to the maximally exposed individual
Annual Average Undepleted/No Decay χ/Q Value @ Nearest Meat Animal	1.4×10^{-6} s/m^3	The maximum annual average meat animal undepleted/no decay χ/Q value for use in determining gaseous pathway doses to the maximally exposed individual
Annual Average Undepleted/2.26-Day Decay χ/Q Value @ Nearest Meat Animal	1.4×10^{-6} s/m^3	The maximum annual average meat animal undepleted/2.26-day decay χ/Q value for use in determining gaseous pathway doses to the maximally exposed individual
Annual Average Depleted/8.00-Day Decay χ/Q Value @ Nearest Meat Animal	1.2×10^{-6} s/m^3	The maximum annual average meat animal depleted/8.00-day decay χ/Q value for use in determining gaseous pathway doses to the maximally exposed individual

SITE CHARACTERISTIC	VALUE	DEFINITION
Annual Average D/Q Value @ Nearest Meat Animal	3.1×10^{-9} 1/m^2	The maximum annual average meat animal D/Q value for use in determining gaseous pathway doses to the maximally exposed individual
Annual Average Undepleted/No Decay χ/Q Value @ Nearest Vegetable Garden	2.0×10^{-6} s/m^3	The maximum annual average vegetable garden undepleted/no decay χ/Q value for use in determining gaseous pathway doses to the maximally exposed individual
Annual Average Undepleted/2.26-Day Decay χ/Q Value @ Nearest Vegetable Garden	2.0×10^{-6} s/m^3	The maximum annual average vegetable garden undepleted/2.26-day decay χ/Q value for use in determining gaseous pathway doses to the maximally exposed individual
Annual Average Depleted/8.00-Day Decay χ/Q Value @ Nearest Vegetable Garden	1.8×10^{-6} s/m^3	The maximum annual average vegetable garden depleted/8.00-day decay χ/Q value for use in determining gaseous pathway doses to the maximally exposed individual
Annual Average D/Q Value @ Nearest Vegetable Garden	6.0×10^{-9} 1/m^2	The maximum annual average vegetable garden D/Q value for use in determining gaseous pathway doses to the maximally exposed individual

2.3.5.4 Conclusions

As set forth above, the applicant has provided meteorological data and an atmospheric dispersion model that are appropriate for the characteristics of the site and release points. The applicant has calculated representative atmospheric transport and diffusion conditions for 16 radial sectors from the site boundary to a distance of 50 miles, as well as for specific receptor locations. The staff has reviewed the long-term atmospheric dispersion estimates that the applicant proposed for inclusion as site characteristics in an ESP for its site (should one be issued) and, for the reasons set forth above, finds these estimates to be acceptable. Therefore, the staff concludes that the applicant has provided the information needed to address the requirements of 10 CFR 100.21(c)(1).

Based on these considerations, the staff concludes that the applicant's characterization of long-term atmospheric transport and diffusion conditions is appropriate for use in demonstrating compliance with the numerical guides for doses contained in Appendix I to 10 CFR Part 50.

The applicant provided bounding values for points of routine release of radioactive material to the atmosphere, the characteristics of each release mode, and the location of potential receptors for dose computations. Any COL or CP applicant must confirm that the parameters provided at the ESP stage bound the actual values provided at the COL or CP stage, and that the calculational methodology used for the confirmation is consistent with that employed at the ESP stage.

2.4 Hydrology

To ensure that a nuclear power plant or plants could be designed, constructed, and operated on the applicant's proposed ESP site in compliance with the Commission's regulations, the NRC staff evaluates hydrology information that may affect the design and siting of such a plant. The staff has prepared Sections 2.4.1 through 2.4.14 of this SER in accordance with the review procedures described in RS-002, using information presented in SSAR Section 2.4, the applicant's responses to RAIs, and generally available reference materials, as described in the applicable sections of RS-002.

The proposed site is adjacent to the currently operating NAPS Units 1 and 2. The water source for the proposed units on the ESP site is the impoundment of the North Anna River, referred to as Lake Anna. Lake Anna currently serves as the principal water source for the two existing units, both of which use once-through cooling systems to dissipate heat from the turbine condenser. The proposed units would also use Lake Anna as the source of cooling water during normal operation. The applicant stated that the proposed Unit 3 would use a once-through cooling system, and the proposed Unit 4 would use a dry cooling tower system for heat rejection during normal operation. Therefore, the water supply needs for Unit 4 would be minimal compared to those of the two existing units and the proposed Unit 3. Neither of the proposed units would rely directly on the lake for safety-related cooling needs. If the selected plant design includes a UHS for each of the proposed units, it would consist of mechanical draft towers over a buried engineered water storage basin.

2.4.1 Hydrologic Description

2.4.1.1 Technical Information in the Application

SSAR Section 2.4.1 states that the ESP site is located near Lake Anna, which was created by a dam constructed across the North Anna River as part of the overall development of the NAPS site. The North Anna Dam is located about 4 miles north of Bumpass, Virginia, and about 5 miles downstream from the ESP site. Lake Anna is about 17 miles long, with an irregular shoreline approximately 272 miles in length.

A series of dikes and canals separates Lake Anna into two segments. The larger segment, approximately 9600 ac in area, is named the North Anna Reservoir and serves as the storage impoundment. The smaller segment, approximately 3400 ac in area, is the WHTF and functions to dissipate heat to the atmosphere from cooling water that has been discharged from the existing units.

The applicant stated that the North Anna Dam is the only significant water control structure on the North Anna River. The dam is an earth-filled structure, approximately 5000 ft long and 30 ft wide at the crest at an elevation of 265 ft mean sea level (MSL).[1] The dam has a 200-ft-long

[1]Mean Sea Level (MSL): A datum, or "plane of zero elevation," established by averaging all stages of oceanic tides over a 19-year tidal cycle or "epoch." This plane is corrected for the curvature of the earth and is the standard reference for elevations on the earth's surface. Another term for MSL is the National Geodetic Vertical Datum.

concrete spillway founded on bedrock. The spillway has three radial crest gates, each of which is 40 ft wide and 35 ft high. Two skimmer gates, each 8.5 ft by 8.5 ft, allow regulation of small discharges.

SSAR Section 2.4.1 states that the proposed ESP site will house two new reactor units. However, the applicant did not clearly demarcate the proposed locations of the units through survey coordinates, making it difficult to determine the feasibility of constructing intake tunnels and related structures. In RAI 2.4.1-1, the staff requested additional information on these survey coordinates, locations of any existing aquifers in the ESP site area, layout of intake tunnels and pipes from Lake Anna to the proposed new units, total service water flow rate for the two existing units, and the combined service water flow rate when all four units (two existing and two new) would be operating. In response to RAI 2.4.1-1, the applicant provided a figure that lists coordinates of the ESP plant perimeter corners. Regarding aquifers, the applicant stated that the subsurface beneath the ESP site consists of a single aquifer that belongs to the Piedmont Physiographic Province aquifer system. Other aquifers nearest the ESP site belong to the Coastal Plain Physiographic Province, but occur about 15 miles away. The applicant stated that, because the entire subsurface beneath the ESP site belongs to a single aquifer system, a drawing of the aquifer system is not required.

The applicant also stated in this RAI response that intake tunnels for Unit 3 will be routed from the ESP intake area about 200 ft south to the ESP footprint, and the discharge tunnel for Unit 3 will be routed from the ESP footprint about 1900 ft east to the ESP discharge. The applicant stated that adequate space is available for these tunnels to ensure that they would not interfere with the underground piping and structures of the existing units.

The applicant also stated that the service water reservoir supplies service water for NAPS Units 1 and 2. The service water system for Units 1 and 2 is a single, two-loop system. Four pumps with a capacity of 11,500 gallons per minute (gpm), two for each unit, service these two loops. Two of these pumps operate during normal operation, three during a unit shutdown, and all four during an accident condition. Two more identical pumps are located in the intake structure as backup to the normal service water supply. The applicant stated that the service water flowpath for any additional units on the ESP site is not defined, but that service water flows can be estimated to be approximately 5 percent of total circulating water flow.

The applicant stated that the non-safety-related cooling water need for all four units, including the proposed additional units, is 121 cubic feed per second (cfs), which includes both natural and forced evaporation from the lake. The applicant estimated a margin of 209 cfs in the water budget, assuming that the average net inflow of 370 cfs is available, with a minimum release of 40 cfs from Lake Anna.

The applicant revised the SSAR to be consistent with the above RAI responses.

SSAR Section 2.4.1.1 originally stated that, during critical low-flow periods, makeup water for cooling would be obtained from Lake Anna and supplemented by an external source that the COL applicant would identify. In RAI 2.4.1-2, the staff requested that the applicant identify the quantity of supplemental water. In response to RAI 2.4.1-2, the applicant stated that, because of uncertainty concerning the adequacy of makeup water for the proposed Unit 4, it changed the cooling system from wet cooling towers to dry cooling towers. The applicant informed the NRC of a revised approach to cooling the proposed Unit 4 in a letter dated March 31, 2004.

The applicant stated that dry cooling towers have no evaporative water losses, require no makeup water, and have no blowdown discharges. However, if the dry cooling tower system contains a secondary cooling water loop with a free water surface pump sump, a small amount of evaporation loss, on the order of 1 gpm, would occur. The applicant stated that, with this change in the cooling system, the consumptive cooling water use for the proposed Unit 4 would decrease from 35 cfs to 0.002 cfs or less during normal plant operation. The applicant revised the SSAR to be consistent with these RAI responses.

Figure 2.4-10 in the SSAR shows the combined stage-storage relationship for Lake Anna and the WHTF. In RAI 2.4.1-3, the staff requested that the applicant provide the data for and a description of the method used to construct this stage-storage relationship. The staff indicated that the stage-storage relationship should extend at least down to stage elevation 219 ft MSL. In response to RAI 2.4.1-3, the applicant stated that it derived the stage-storage curve for Lake Anna from topographic contour maps. The applicant constructed contour maps from aerial photogrammetry of the proposed lake area before the North Anna Dam was built. It measured surface areas enclosed by the contours using a planimeter, and it determined incremental storage volume between two contours, assuming a truncated square pyramid shape between these contours. The applicant checked the stage-storage curve for accuracy on photo sheets and on U.S. Geological Survey (USGS) topographic maps. The applicant also provided a table showing the stage-storage curve and revised the SSAR to be consistent with the RAI response.

In SSAR Section 2.4.1.1, the applicant stated that the cooling water withdrawal rate for Unit 3 will be 2540 cfs, and that for Unit 4 this rate will be 44 cfs. In RAI 2.4.1-4, the staff requested that the applicant clarify whether these values are based upon annual averages or maximums. If these values are annual averages, the staff asked the applicant to provide estimates of maximums. In RAI 2.4.1-4, the staff also requested the applicant to provide the basis for the estimation of consumptive loss from the Unit 4 cooling tower. In response to RAI 2.4.1-4, the applicant stated that the cooling water withdrawal rate of 2540 cfs for Unit 3 is a nominal design coolant flow. This is the nominal flow during periods of peak lake temperature. The applicant stated that the actual daily maximum circulating water flow for Unit 3 would be within a few percent of the nominal value. The applicant informed the NRC of a revised approach to cooling the proposed Unit 4 in a letter dated March 31, 2004, and subsequently revised the SSAR to reflect this approach. The revised application states that the proposed Unit 4 would use a closed-cycle cooling system with dry cooling towers. This approach eliminates the use of Lake Anna as a source of makeup water for Unit 4. The applicant also stated that the secondary cooling loop evaporative losses for the proposed Unit 4 may consume a small amount of water, on the order of 1 gpm.

2.4.1.2 Regulatory Evaluation

Section 1.8 of the SSAR presents a detailed discussion of the applicant's conformance to NRC regulations and regulatory guidance. The applicant identified the applicable regulations as GDC 2 in Appendix A to 10 CFR Part 50, 10 CFR 52.17(a), and 10 CFR 100.20(c), as well as the applicable regulatory guidance, RG 1.70 and RS-002. The staff reviewed this portion of the application for conformance with the applicable regulations, and considered the corresponding regulatory guidance, as identified above, with the exception that an ESP applicant need not demonstrate compliance with the GDC.

Section 2.4.1 of RS-002 provides the following review guidance used by the staff in evaluating this SSAR section.

The SSAR should address 10 CFR Parts 52 and 100, as they relate to identifying and evaluating hydrologic features of the site. The regulations at 10 CFR 52.17(a) and 10 CFR 100.20(c) require that the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) be taken into account to determine its acceptability for a nuclear power reactor. In addition, 10 CFR 100.20(c) addresses the hydrologic characteristics of a proposed site that may affect the consequences of an escape of radioactive material from the facility. Factors important to hydrologic radionuclide transport, described in 10 CFR 100.20(c)(3), should be obtained from onsite measurements. The staff evaluated SSAR Section 2.4.1 in light of these requirements.

To satisfy the hydrologic requirements of 10 CFR Parts 52 and 100, the applicant's SSAR should contain a description of the surface and subsurface hydrologic characteristics of the site and region. This description should be sufficient to assess the acceptability of the site and the potential for those characteristics to influence the design of the SSCs of a nuclear power plant or plants (or a facility falling within a PPE) that might be constructed on the proposed site.

Meeting this guidance provides reasonable assurance that the hydrologic characteristics of the site and potential hydrologic phenomena would pose no undue risk to the type of facility (or facility falling within a PPE) proposed for the site. Further, it provides reasonable assurance that such a facility would pose no undue risk of radioactive contamination to surface or subsurface water from either normal operations or as the result of a reactor accident.

To meet the requirements of the hydrologic aspects of 10 CFR Parts 52 and 100, SSAR Section 2.4.1 should form the basis for hydrologic engineering analysis with respect to subsequent sections of the application for an ESP. Therefore, completeness and clarity are of paramount importance. Maps should be legible and adequate in coverage to substantiate applicable data. Site topographic maps should be of good quality and of sufficient scale to allow independent analysis of preconstruction drainage patterns. Data on surface water users, location with respect to the site, type of use, and quantity of surface water used are necessary. Inventories of surface water users should be consistent with regional hydrologic inventories reported by applicable Federal and State agencies. The description of the hydrologic characteristics of streams, lakes, and shore regions should correspond to those of the USGS, NOAA, Soil Conservation Service (SCS), U.S. Army Corps of Engineers (USACE), or appropriate State and river basin agencies. Descriptions of all existing or proposed reservoirs and dams (both upstream and downstream) that could influence conditions at the site should be provided. Descriptions may be obtained from reports of the USGS, U.S. Bureau of Reclamation (USBR), USACE, and others. Generally, reservoir descriptions of a quality similar to those contained in pertinent data sheets of a standard USACE hydrology design memorandum are adequate. Tabulations of drainage areas, types of structures, appurtenances, ownership, seismic and spillway design criteria, elevation-storage relationships, and short- and long-term storage allocations should be provided.

2.4.1.3 Technical Evaluation

The staff conducted a site visit in accordance with the guidance provided in Section 2.4.1 of RS-002. The staff used information from the site visit, digital maps, and streamflow data from the USGS to verify the hydrologic description provided in Section 2.4.1 of the SSAR. Because Virginia Electric and Power Company (which, like the applicant, is a subsidiary of Dominion Resources, Inc.) built the reservoir and continues to operate it, the company has a large volume of historical data pertaining to the reservoir. The applicant has supplemented that data with maps, charts, and data from Federal, State, and regulatory bodies describing hydrologic characteristics and water use in the site vicinity.

The staff verified the combined surface area of Lake Anna and the WHTF using the USACE major dams map layer. This map layer dataset lists the combined surface area of Lake Anna and the WHTF as 13,000 ac, compared to 13,096 ac reported by the applicant.

The applicant stated in SSAR Section 2.4.1.2.1 that the catchment area of the North Anna River above the North Anna Dam is about 343 mi^2. The staff verified this statement by comparing the catchment area reported by the applicant with the 344 mi^2 drainage area of USGS streamflow gauge 01670400, at the North Anna River near Partlow, Virginia. The applicant stated in SSAR Section 2.4.1.2.1 that the discharge measured at the Partlow streamflow gauge reflects the regulated outflow from Lake Anna for the entire period of record since the dam was completed in 1972. The staff notes that measurements of discharge from the dam are not available from the closure of the dam sometime in 1972 until October 1, 1978.

The staff independently searched for streamflow gauges in the site vicinity and found that the USGS has maintained four streamflow gauges near the plant. Two gauges measured streamflows of tributaries draining into Lake Anna, and two measured streamflows downstream of the Lake Anna Dam. The longest streamflow record exists for the North Anna River near the Doswell, Virginia, gauge. This gauge reflects the release from Lake Anna and runoff from an additional 97 mi^2 of watershed downstream of the Lake Anna Dam. Streamflow at this gauge was recorded from April 1929 through October 1988. Streamflow immediately downstream from the Lake Anna Dam (North Anna River near Partlow, Virginia) was recorded from October 1978 through October 1995. The gauge on Contrary Creek, which drains into Lake Anna, reflects only 5.53 mi^2 of the watershed and has a record from October 1975 through January 1987. Another stream gauge upstream of Lake Anna (Pamunkey Creek at Lahore, Virginia) records runoff from 40.5 mi^2 of the Pamunkey Creek drainage area for the period from August 1989 through July 1993. The two upstream gauges record flows representative of only 46 mi^2, or approximately 13 percent of the total upstream area contributing flow to Lake Anna. The staff could not use the limited upstream tributary inflow data to independently estimate historical frequency distribution of water levels at the ESP site. Consequently, the staff used a different empirical approach to estimate low-water conditions at the ESP site, as discussed in Section 2.4.11.3 of this SER.

In RAI 2.4.1-1, the staff requested additional information on coordinates of grid sectors for the individual NAPS units. The staff also requested a layout of the intake piping/tunnel from the lake to the proposed units and locations of existing perched aquifers in the site area to demonstrate ESP site feasibility. In this RAI, the staff asked the applicant to provide the total service water flow rate needed for the two existing units with once-through cooling systems, as well as the integrated cooling flow demand for all four units, to determine whether sufficient margin exists in the available water flow from the North Anna Reservoir to account for any uncertainties associated with water and land-use changes in the vicinity of the plant.

The applicant's response to RAI 2.4.1-1 included a figure that lists the coordinates of the corners of the ESP PPE (ESP site footprint). However, the applicant did not identify the coordinate system. The staff needed information regarding the coordinate reference system and the units of these coordinates to fully define the boundaries of the ESP site footprint. This was Open Item 2.4-1. The staff identified in Open Item 2.4-1 the need for information regarding the coordinate reference system and the units of measurement of these coordinates to fully define the boundaries of the ESP site footprint.

In its submittal dated March 3, 2005 (Dominion, "Responses to Draft Safety Evaluation Report Open Items"), the applicant stated that map coordinates used the Virginia State Plane North American Datum (NAD) 83 South Zone coordinate system, and that map coordinates are expressed in feet. The staff reviewed the applicant's response and determined that the additional information provided by the applicant is sufficient to fully define the boundaries of the ESP site footprint. Accordingly, the staff considers Open Item 2.4-1 to be resolved.

In response to RAI 2.4.1-1, the applicant explained that unconfined aquifer conditions exists beneath the ESP site in the unconsolidated deposits and bedrock, which form the Piedmont Physiographic Province aquifer system. (Unconfined aquifer conditions are those in which there is no impervious layer confining the water bearing strata.) Since the ESP site and the general area are underlain by the Piedmont Physiographic Province aquifer system, the staff finds that there is no concern regarding perched aquifers at the ESP site.

The applicant provided a figure that contains a layout of the ESP intake and discharge tunnels. Based on SSAR Figure 1.2-4, the staff determined that parts of the ESP intake and discharge tunnels will be located outside the PPE (ESP footprint). In the DSER, the staff stated that the applicant needed to specify minimum distances from the SSCs of the existing units to the ESP intake and discharge tunnels to ensure that no interference will occur with SSCs of the existing units. This was Open Item 2.4-2. The staff planned to impose these distances as DSER Permit Condition 2.4-1 to ensure that no such interference would occur if a COL or CP were ultimately granted.

In response to Open Item 2.4-2, the applicant explained in its submittal dated March 3, 2005, that the discharge tunnel for proposed Unit 3 would be routed from the ESP footprint east a distance of up to 1800 ft to the ESP discharge. SSAR Figure 1.2-4 shows the locations of the ESP intake area, the ESP footprint, and the ESP discharge. These layouts generally coincide with those originally planned for abandoned Units 3 and 4, which were never completed. The proposed Unit 4 would use a closed-cycle cooling system with dry cooling towers to transfer rejected heat to the atmosphere. As shown in SSAR Figure 1.2-4, proposed Unit 3 would have its own intake west of the existing units' intake and its own outfall adjacent to the existing units' outfall at the head of the discharge canal. The preliminary construction strategy would be to use existing structures and routes to the extent possible. In the event that the existing tunnels from the abandoned units are deemed unsuitable, new tunnels would be constructed in the same vicinity. While the routing for these tunnels would pass beneath roadways, power lines, fence lines, and other structures, the tunnels would remain well away from the existing units' major powerblock structures.

In its response, the applicant also described potential construction techniques that could be used to build the new discharge tunnel, and it stated that it would be feasible to perform the construction activities associated with the intake and discharge tunnels with no adverse interactions with the existing units' SSCs. Based on the above, the staff has determined that it is feasible to construct the proposed Unit 3 discharge tunnel in the future, should the existing abandoned discharge tunnel be determined to be unsuitable during the design of the proposed Unit 3. Any construction on the ESP site prior to issuance of a COL or CP will be constrained by the existing plants' operating licenses as governed by 10 CFR Part 50, including the requirements of 10 CFR 50.59. Since the current licensee controls access to the exclusion area, as described in Section 2.1.2 of this SER, the holder of any ESP issued for the North Anna site, and any COL or CP applicant referencing such an ESP will be able to construct and operate a new unit only in accordance with the terms of an agreement with the licensee of the existing units. The licensee of the existing units is obligated to satisfy the provisions of 10 CFR 50.59, and it will ensure that such an agreement reflects the results of any evaluation performed pursuant to 10 CFR 50.59. Accordingly, the requirements of Part 50 will ensure that any changes to the existing units SSCs resulting from construction on the ESP site will be adequately controlled. Therefore, the staff has determined that it is not necessary to impose DSER Permit Condition 2.4-1.

For this site permit review, the staff does not endorse any proposed construction technique; instead, the applicant's response is used only for a feasibility determination. The Section 50.59 process, or, should discharge tunnel construction be described in a COL or CP application, the future COL or CP review process will ensure the safety of any new construction. In the latter circumstance, the staff would review the layout of intake and discharge tunnels and the construction techniques to be used by any COL or CP applicant before commencement of construction activities. This is **COL Action Item 2.4-1.** Based on the above, the staff considers Open Item 2.4-2 to be resolved.

The applicant estimated a margin of 209 cfs in the water budget, assuming that the average net inflow of 370 cfs would be available. All units, including the proposed additional units, need 121 cfs of non-safety-related cooling water. The State of Virginia requires a minimum release of 40 cfs from Lake Anna for water surface elevation at or above 248 ft MSL and a minimum release of 20 cfs below it. However, during periods of low flow, the expected inflow into Lake Anna can be substantially lower than the average inflow. These periods may be critical for non-safety-related cooling needs. The staff asked the applicant to describe the potential impacts of low-flow conditions on the operation of all units. This was Open Item 2.4-3.

In response to Open Item 2.4-3, the applicant stated, in its submittal dated March 3, 2005, that Section 5.2.2 of the environmental report describes a water budget analysis carried out to determine potential impacts of low-flow conditions on the operation of all units. The applicant carried out the water budget analysis to assess potential impacts of low-flow conditions on the operation of all units. This analysis determined that the minimum water surface elevation in Lake Anna during the simulation period, which included the severe 2001–2002 drought, would be 242.6 ft MSL when proposed Unit 3 is assumed to operate along with NAPS Units 1 and 2.

The applicant also stated that, at the time of the submission of the SSAR, modifications were underway to reconfigure the intake of NAPS Units 1 and 2 to allow operation of these units down to a low water surface shutdown elevation of 242 ft MSL. These modifications were complete as of March 3, 2005, the date of applicant's response to staff's open items. The low water surface shutdown elevation for operation of NAPS Units 1 and 2, and of proposed Unit 3, is now 242 ft MSL. The applicant stated that, since the low water surface shutdown elevation in

Lake Anna for normal operation of proposed Unit 3 (242 ft MSL) is less than the minimum water surface elevation determined by applicant's water budget analysis (242.6 ft MSL), the normal operation of proposed Unit 3 would not be impacted, even during extended periods of low inflow to Lake Anna.

The staff evaluated the water budget as set forth below. The staff estimated inflows for the drainage upstream of Lake Anna using data from the adjacent Little River drainage basin adjusted for the differences in drainage areas. The reason for using an adjacent drainage basin is that too few of the tributaries flowing into Lake Anna are gauged for the data to be useful in constructing an inflow sequence for the analysis. The staff also decided that the flow downstream from Lake Anna Dam cannot be used to estimate inflows to Lake Anna because they are too heavily influenced by consumptive losses from Units 1 and 2 and the flow regulation resulting from the lake. The Little River drainage is a 107 mi^2 area adjacent to the North Anna drainage with streamflow measurements from October 1961 to the present. The direct precipitation input to the lake was based on precipitation records from the meteorological station at the Richmond, Virginia airport.

The staff estimated outflows from the lake based on the current operating rules for the Lake Anna Dam, which are regulated by the State of Virginia. Releases are generally performed to maintain a water surface elevation of 250 ft MSL. When the water surface elevation drops below 250 ft MSL because of inadequate inflow to offset the natural and induced evaporative losses, the release is maintained at the normal minimum flow of 40 cfs. If the water surface elevation declines below 248 ft MSL, releases were assumed to decrease to 20 cfs immediately. The minimum operating depth for the intake pumps for ESP Unit 3 as well as those for Units 1 and 2 is 242 ft MSL.

Based on the applicant's PPE estimate of 29 cfs, the staff-estimated minimum lake elevation that would occur anytime during the period from 1978–2003 was 242.8 ft MSL. Therefore, the staff concluded that any drop below 242 ft MSL would be infrequent.

The staff's water budget analysis also addressed the gradual decrease in water surface elevation in Lake Anna during normal operation of all units, including the proposed Unit 3, for an extended period of time that also included a severe 2-year drought during water years 2001 and 2002. The staff used precipitation data from the Richmond, Virginia, airport (period of record from January 1, 1921, to May 31, 2004) in its water budget analysis. In terms of precipitation, water year 1924 was the driest, and water year 2002 was the second driest. Combined precipitation during water years 2001 and 2002 was the driest 2-year period in the record.

The staff's concern in Open Item 2.4-3 was to determine if water surface elevation in Lake Anna could fall rapidly and/or frequently enough to result in an excessive reliance of proposed Unit 3 on its UHS, if the selected plant design includes a UHS.

The staff's water budget analysis estimated that, during the severe 2001–2002 2-year historical drought, the water surface elevation in Lake Anna would not have fallen below 242.6 ft MSL with the existing units running at full capacity and the proposed Unit 3 running using a once-through cooling system, also at full capacity. In an alternative configuration, with the existing units running at full capacity and the proposed Unit 3 operating at full capacity with a wet cooling tower, water surface elevation in Lake Anna would have fallen to 242 ft MSL, the proposed low water surface elevation for shutdown of proposed Unit 3. The staff used conservative estimates of consumptive water use by the Unit 3 wet cooling tower for this alternative configuration. In this alternative configuration, it took 71 days for water surface elevation in Lake Anna to fall from 244 ft MSL to 242 ft MSL. While it is possible for a more rapid decrease in water surface elevation in Lake Anna to occur in the presence of a more severe combination of starting water surface elevation, low inflow, and little precipitation, the staff considers the 71-day period for the water surface elevation to fall from 244 ft MSL to 242 ft MSL indicative of Lake Anna's large capacity to allow a gradual decrease in its water surface elevation, even under extreme droughts. Therefore, the staff concludes that water surface elevation in Lake Anna does not fall rapidly and that sufficient time will be available to plant operators before the low water surface elevation shutdown threshold is reached to plan a shutdown of the proposed Unit 3 without endangering its safety, even under severe drought conditions. Based on the staff's independent water budget analysis described above, the staff also concludes that the water surface elevation in Lake Anna does not fall near the low water surface elevation shutdown threshold frequently enough to result in an excessive reliance of Unit 3 on its UHS, if the selected plant design includes a UHS. Accordingly, the staff considers Open Item 2.4-3 to be resolved.

SSAR Section 2.4.1.1 originally stated that, during critical, low-flow periods, makeup water would be obtained from Lake Anna, supplemented by an external source which the COL applicant would identify. In RAI 2.4.1-2, the staff requested that the applicant identify the source and quantity of the makeup flow. The applicant informed the NRC in a letter dated March 31, 2004, that proposed Unit 4 would use dry cooling towers as its normal cooling system. The applicant stated that the change in the proposed Unit 4 cooling system from wet cooling towers to dry cooling towers will reduce its consumptive water use from 35 cfs to approximately 0.002 cfs. The change of the proposed Unit 4 cooling system to a dry cooling system eliminates the need for any significant quantity of alternative cooling water. The applicant has revised its application to commit to a dry cooling system for the proposed Unit 4. This is a satisfactory response to RAI 2.4.1-2.

Subsequently, the staff based its water budget analysis and interpretation of its results on the assumption that the proposed Unit 4 would use a negligible amount of water (on the order of 1 gpm) from Lake Anna for its normal cooling. In order to ensure the safety of any proposed nuclear power plant or plants that may be built on the ESP site, the NRC staff proposes to include a condition in any ESP that might be issued for this site requiring that an applicant for a fourth proposed unit use a dry cooling tower system during normal operation. This is **Permit Condition 3.** In addition, any COL or CP applicant should develop a plant shutdown protocol for proposed Unit 3 when water surface elevation in Lake Anna falls to 242 ft MSL. This is **COL Action Item 2.4-2.**

The staff independently obtained estimates of the stage-storage relationship for Lake Anna. The staff obtained USGS 1:24,000 digital raster graph maps for Lake Anna and mosaicked them to create a georeferenced topographic map using the geographical information system software, ArcMap, Version 9.0. The bathymetry contours on this topographic map have elevations from 180 to 250 ft MSL. The staff manually digitized the lake boundary and the bathymetry contour lines and corrected them for errors. The staff created a digital surface using these digitized contours. The staff created horizontal sections, or isosurfaces, of this digital surface from 180 to 250 ft MSL at 10 ft intervals. The staff digitally determined areas of these isosurfaces and then calculated the enclosed volume between two successive isosurfaces to independently estimate the stage-storage relationship for Lake Anna. The staff's independent estimates closely match the applicant's stage-storage curve. Therefore, the staff considers the applicant's curve to be satisfactory.

SSAR Section 2.4.1.1 reports an estimated withdrawal of 2540 cfs for Unit 3 and 44 cfs for the proposed Unit 4. A subsequent letter from the applicant to the NRC dated March 31, 2004, stated that the proposed Unit 4 would use a dry cooling tower. In RAI 2.4.1-4, the staff requested the applicant to clarify whether the cooling water flow values are annual averages or maximums. The staff indicated that if they were annual averages, estimates for daily maximums were needed. In its response, the applicant stated that the cooling water flow rate of 2540 cfs for the proposed Unit 3 is a nominal value and that the daily maximum flow rate would be within a few percent of this nominal value. In addition, proposed Unit 4 secondary cooling loop evaporative issues will consume a small amount of water, on the order of 1 gpm.

Based on information provided in the SSAR and the applicant's response to the RAIs discussed in this section of the SER, the staff concludes that the additional water budget available for use by the new units is 2540 cfs. The staff intended to identify this maximum water use as DSER Permit Condition 2.4-2. Since the available water flow is at least equal to the controlling PPE value of 2540 cfs, and Appendix A of this SER identifies the controlling PPE values, it is not necessary to add this permit condition. The future review process will ensure that a new plant's cooling water use is safely limited to the amount of water flow not to exceed 2540 cfs. The PPE Table 3.1-1 of the application states that the bounding Unit 3 discharge water temperature is 113 °F, and the cooling water temperature rise is 18 °F, which results in a maximum inlet temperature limit of 95 °F. Since the available water flow rate depends upon these conditions, the staff proposes to include these controlling PPE values in any ESP that the NRC might issue for the site. Pursuant to 10 CFR 52.24, the staff proposes the cooling water flow rate of 2540 cfs, the cooling water temperature rise of 18 °F, and the maximum inlet temperature of 95 °F as controlling PPE values when the lake level is less than or equal to 244 ft MSL. Appendix A of this SER lists the controlling PPE values. Any COL or CP applicant referencing an ESP issued for the North Anna site should show that the combined cooling water flow rate for the new units does not exceed 2540 cfs. This is **COL Action Item 2.4-3.**

2.4.1.4 Conclusions

As set forth above, the applicant has provided information pertaining to the general hydrologic characteristics of the site, including descriptions of rivers, streams, and lakes; water-control structures; and users of waters. Therefore, the staff concludes that, with the noted conditions, the applicant has met the requirements regarding general hydrologic descriptions with respect to 10 CFR 52.17(a) and 10 CFR 100.20(c).

2.4.2 Floods

2.4.2.1 Technical Information in the Application

Lake Anna was created to provide a reliable supply of cooling water for NAPS. The watershed that drains into Lake Anna is approximately 323 mi^2. The area of Lake Anna, including the WHTF, is approximately 20 mi^2. The North Anna Dam is located about 4 miles north of

Bumpass, Virginia, and about 5 miles downstream from the ESP site. Lake Anna is about 17 miles long, with an irregular shoreline approximately 272 miles in length.

The applicant presented peak flood discharges and peak reservoir levels for Lake Anna (since 1979) in SSAR Section 2.4.2.1. The largest flood recorded on the North Anna River at the Doswell, Virginia, gauge station occurred in 1969, with a peak discharge of 24,800 cfs. The applicant reported that the flood of 1972 that resulted from Hurricane Agnes was 24,000 cfs and nearly matched the historical peak discharge. However, it was attenuated at the time by the recently completed, but only partially filled, Lake Anna.

In SSAR Section 2.4.2.2, the applicant considered several possibilities for determining its design-basis flood, including the probable maximum flood (PMF) on streams and rivers, potential dam failures, the probable maximum surge and seiche[2] flood, and ice-effect flooding. The applicant selected the highest water level from among these flooding possibilities as the maximum flooding level. The highest water level in Lake Anna results from the PMF produced by the probable maximum precipitation (PMP) over the lake's watershed. The applicant's analysis estimates a design-basis flood elevation of 267.39 ft at the ESP site.

The staff requested, in RAI 2.4.2-1, that the applicant provide a description of likely upstream land-use changes and changes in downstream water demand that would alter both flood risk and the intensity and frequency of low-flow conditions. The staff indicated that factors affecting potential runoff (such as urbanization, forest fire, or change in agricultural use), erosion, and sediment deposition needed to be considered for determining flood elevation at the ESP site. In addressing RAI 2.4.2-1, the applicant stated that its response to environmental RAI E4.2.2-2 describes likely upstream land-use changes and downstream water demand. The applicant identified three counties located upstream of Lake Anna that may undergo growth. New development could lead to an increase in impervious surface area and, consequently, an increase in runoff to Lake Anna. The applicant stated that all three counties plan to implement stormwater management measures to reduce downstream impacts. The projected development in these counties is low, and the applicant expects such development to result in only a small impact to Lake Anna. The applicant also described the potential effect of forest fires and consequent sediment deposition in Lake Anna and concluded that these effects will not affect flood-level determination. The applicant stated that an increase in water demand resulting from the proposed Unit 3 would lead to longer periods when the lake level will be below 250 ft MSL, as compared to existing conditions. The applicant proposed that the presence and operation of the proposed Unit 3 may increase the likelihood that the lake level will be below 250 ft MSL when a flood event occurred. Since more storage will be available under such circumstances, the applicant concluded that the flood-water level at the ESP site would be reduced. The applicant revised the SSAR to be consistent with its RAI response.

The staff requested, in RAI 2.4.2-2, that the applicant provide its methodology for documenting hillslope failures in the watershed of Lake Anna. The staff indicated that any documented hillslope failures should include both the failure mechanism and the hillslope properties (e.g., terrain grade, drainage, and soil type). In response to RAI 2.4.2-2, the applicant stated that it

[2] A seiche is a standing wave oscillation of an enclosed water body that continues, pendulum fashion, after the cessation of the originating force, which may have been either seismic or atmospheric (USACE 2003).

had investigated landslide hazards in the North Anna site area. The applicant used field reconnaissance, air photo interpretation, literature search, and discussions with researchers familiar with the region. The applicant determined that large, deep-seated landslides do not occur in the North Anna site area or along the shores of Lake Anna. The topography in the Piedmont region is not susceptible to landslides and extensive debris flows. The applicant found no published maps of landslides in the Lake Anna area. The applicant concluded that no potential exists for large, deep-seated landslides or debris flows that may produce a seiche in Lake Anna.

The staff requested, in RAI 2.4.2-3, that the applicant provide its methodology for documenting seismically induced seiches in Lake Anna. The staff indicated that any evidence of a historical seismically induced seiche in the area should include a description of the seismic event, land damage, date of occurrence, and other information. In response to RAI 2.4.2-3, the applicant stated that it performed a literature search to determine if any seismically induced seiches had occurred in Lake Anna or other lakes in the area. In its response, the applicant referred to a paper published in the *Science of Tsunami Hazards*, the international journal of the Tsunami Society. This paper lists all known reports of tsunami and tsunami-like waves, including seiches, that have occurred in the eastern United States since 1600. The applicant found no listings of seiche activity in Virginia in the paper. The applicant also stated that the plant personnel at North Anna have not reported any seiches on Lake Anna.

The staff requested, in RAI 2.4.2-4, that the applicant demonstrate that drainage capacity at the existing grade is sufficient to accommodate local, intense precipitation. If this capacity is not sufficient, the staff asked the applicant to describe any active, safety-related drainage systems that will be installed for the ESP units. In addition, the staff requested the applicant to indicate whether drainage from the proposed site would use a drainage canal under the existing railroad spur. In its response, the applicant stated that the final grade at the ESP site would slope gently from south to north toward Lake Anna. The applicant stated that it would determine the final grade of the site after completing a detailed analysis for drainage of local intense precipitation (i.e., the local PMP defined in SSAR Section 2.4.2.3). The applicant proposed to drain local intense precipitation using surface ditches and swales. The applicant described two scenarios related to the existing railroad spur. If the spur is left in place, drainage culverts would be needed. Flood analysis for local intense precipitation would assume that all culverts are blocked, and grading near the railroad spur would be provided to allow floodwater to flow over the railroad spur and the road located north of it. Grading north of the road would be provided to direct floodwater to a surface ditch that would discharge to Lake Anna. If the railroad spur is removed, the road north of it would be provided with a low-water crossing consisting of a wide drainage canal at an elevation lower than the existing elevation of the road. The applicant also proposed to provide a storm drain beneath this drainage canal to discharge flow generated by less severe storms. For either of these scenarios, the applicant stated that slab and entrance curb elevations for safety-related facilities would be placed above the flood elevations determined from a detailed analysis of flooding caused by local intense precipitation.

2.4.2.2 Regulatory Evaluation

Section 1.8 of the SSAR presents a detailed discussion of the applicant's conformance to the NRC regulations and regulatory guidance. The applicant identified the applicable regulations as Appendix S, "Earthquake Engineering for Nuclear Power Plants," to 10 CFR Part 50, 10 CFR 52.17(a), and 10 CFR 100.20(c) and the applicable regulatory guidance, RGs 1.29, "Seismic

Design Classification"; 1.59, "Design Basis Floods for Nuclear Power Plants"; 1.70; and 1.102, "Flood Protection for Nuclear Power Plants"; as well as RS-002. The staff reviewed this portion of the application for conformance with the applicable regulations, and considered the corresponding regulatory guidance, as identified above.

Section 2.4.2 of RS-002 provides the following review guidance the staff used in evaluating this SSAR section.

Acceptance criteria for this section address 10 CFR Parts 52 and 100, as they relate to identifying and evaluating hydrologic features of the site. The regulations at 10 CFR 52.17(a) and 10 CFR 100.20(c) require that the site's physical characteristics (including seismology, meteorology, geology, and hydrology) be taken into account when determining its acceptability to host a nuclear reactor or reactors.

To satisfy the hydrologic requirements of 10 CFR Parts 52 and 100, the SSAR should contain a description of the surface and subsurface hydrologic characteristics of the site and region and an analysis of the PMF. This description should be sufficient to assess the acceptability of the site and the potential for those characteristics to influence the design of plant SSCs important to safety. Meeting this guidance provides reasonable assurance that the hydrologic characteristics of the site and potential hydrologic phenomena would pose no undue risk to the type of facility proposed for the site.

For those cases in which a reactor design is not specified, the ESP applicant may instead provide a PPE to characterize a facility or facilities for comparison with the hydrologic characteristics of the site. A PPE can be developed for a single type of facility or a group of candidate facilities by selecting the relevant limiting parameters.

To determine whether the applicant met the requirements of the hydrologic aspects of 10 CFR Parts 52 and 100, the staff used the following specific criteria:

- For SSAR Section 2.4.2.1, the staff compares the potential flood sources and flood response characteristics of the region and site identified by its review (as described in the review procedures) to those identified by the applicant. If similar, the staff accepts the applicant's conclusions. If, in the staff's opinion, significant discrepancies exist, the staff will ask the applicant to provide additional data, reestimate the effects on a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the proposed site, or revise the applicable flood design bases, as appropriate.

- For the SSAR Section 2.4.2.2, the applicant's estimate of controlling flood levels is acceptable if it is no more than 5 percent less conservative than the staff's independently determined (or verified) estimate. If the applicant's SSAR estimate is more than 5 percent less conservative, the applicant should fully document and justify its estimate of the controlling level. Alternatively, the applicant may accept the staff's estimate.

- For SSAR Section 2.4.2.3, the applicant's estimates of the local PMP and the capacity of site drainage facilities (including drainage from the roofs of buildings and site ponding) are acceptable if the estimates are no more than 5 percent less conservative than the corresponding staff assessment. Similarly, conclusions relating to the potential for any adverse effects of blockage of site drainage facilities by debris, ice, or snow should be based upon conservative assumptions of the storm and vegetation conditions likely to exist during storm periods. If a potential hazard does exist (e.g., the elevation of ponding exceeds the elevation of plant access openings), the applicant should document and justify the local PMP basis.

The staff used the appropriate sections of the following documents to determine the acceptability of the applicant's data and analyses in meeting the requirements of 10 CFR Parts 52 and 100. RG 1.59 provides guidance for estimating the design-basis flooding considering the worst single phenomenon, as well as combinations of less severe phenomena. The staff used the publications of USGS, NOAA, SCS, USACE, applicable State and river basin authorities, and other similar agencies to verify the applicant's data relating to the hydrologic characteristics and extreme events in the region.

2.4.2.3 Technical Evaluation

The staff obtained historical flows from USGS streamflow records for the Doswell and Partlow gauges. The peak discharge at Doswell ("Peak Streamflow for the Nation, USGS 01671000 North Anna River Near Doswell, Virginia") during the 1972 flood was 23,300 cfs, and the corresponding peak discharge at Partlow ("Peak Streamflow for the Nation, USGS 01670400 North Anna River near Partlow, Virginia") was 22,000 cfs.

Hydrometeorological Report (HMR) 52 ("Application of Probable Maximum Precipitation Estimates—United States East of the 105th Meridian," National Weather Service, August 1982) states that local intense precipitation at a given site should be based on the short-duration (1 hour), 1-mi^2 PMP. The staff used the HMR 52 guidelines to estimate the 1-hour, 1-mi^2-PMP depth for the ESP site. Column 2 of Table 2.4-1 lists the multiplication factors recommended in HMR 52 that are applied to 1-hour, 1-mi^2 PMP depth to estimate the PMP depths for other durations. Column 3 of Table 2.4.2-1 includes the staff's estimated PMP depths corresponding to these durations.

Table 2.4.2-1 Local Intense Precipitation (1-mi^2 PMP) at the North Anna ESP Site

Duration	Multiplier to 1-hr PMP depth	PMP depth (in.)
5 min	0.331	6.1
15 min	0.522	9.58
30 min	0.748	13.73
1 hr	1.000	18.3
6 hr	1.527	28.02

The estimation of onsite drainage capacity and the availability of cooling water during critical low-flow periods call for margins sufficient to account for future urbanization of the watershed. These margins should be based upon available county and/or State growth management plans. In RAI 2.4.2-1, the staff indicated that a description of likely upstream land-use changes and changes in downstream water demand that could alter both flood risk and the intensity and frequency of low-flow conditions was needed. The staff also indicated that factors affecting potential runoff (e.g., urbanization, forest fire, or change in agricultural use), erosion, and sediment deposition should be considered in the determination of flood elevation at the site.

In response to RAI 2.4.2-1, the applicant described the effects of upstream land-use changes and an increase in downstream water demand. Using this information, and assuming very conservative infiltration loss terms (i.e., low water losses) during computation of flood-water elevations at the ESP site, the staff has verified (as documented in Section 2.4.3 of this SER) that there is reasonable assurance that flooding caused by a PMF occurring in the Lake Anna watershed will not pose an undue risk to a facility falling within the PPE that might be located on the ESP site.

In response to RAI 2.4.2-2, the applicant performed field reconnaissance, literature searches, and consultations with researchers familiar with the region. The applicant found no evidence of large landslides or debris flows in the region that could produce a seiche in Lake Anna. The staff has determined that the applicant has adequately addressed these concerns and that it has provided sufficient information to conclude that hillslope failure leading to a seiche in Lake Anna is not credible.

In response to RAI 2.4.2-3, the applicant performed a literature survey and referred to a paper published in *Science of Tsunami Hazards* that lists all known tsunami and tsunami-like waves, including seiches, which have occurred in the eastern United States since 1600. The applicant did not find any listed event that occurred in Virginia. The applicant stated that plant personnel at North Anna have not reported any such event. Accordingly, the staff concludes that the applicant has adequately addressed the possibility that seismically induced seiches could occur in Lake Anna. The staff's independent estimate, discussed in Section 2.4.5 of this SER, also indicates that seismically induced seiches in Lake Anna are unlikely.

In response to RAI 2.4.2-4, the applicant stated that drainage facilities at the ESP site will be determined after a detailed analysis of flooding resulting from local intense precipitation. The applicant described two possible scenarios, one for the case in which the existing railroad spur is left in place and the other for the case in which the railroad spur is removed. Both scenarios would possibly call for suitable grading at the site, near the railroad spur and near the road located north of the railroad spur, to direct any flood produced by local intense precipitation at the ESP site to Lake Anna.

Drainage systems, such as storm drains or culverts, may become blocked during a flooding event. To preclude the possibility of a safety concern for this reason, the staff intended to specify in DSER Permit Condition 2.4-3 that any COL or CP applicant would be required to design the ESP site grade in such a way as to ensure that any flooding caused by local intense precipitation on the ESP site will be discharged to Lake Anna without relying on such systems. Since detailed design of the plants, including the site grade, are beyond the scope of an ESP review, the staff has determined that it is not necessary to impose DSER Permit Condition 2.4-3.

The staff will review the detailed design of the site grade based on applicable NRC regulations and regulatory guidance if an application is submitted referencing any ESP that might be issued. Any COL or CP applicant should show that the ESP site is graded such that any flooding caused by local intense precipitation will be discharged to Lake Anna even in the event that any and all active drainage systems may be blocked and unable to function. This is **COL Action Item 2.4-4.** Appendix A of this SER identifies the minimum site grade at 271 ft MSL as a controlling PPE value. In addition, the staff intended to specify in DSER Permit Condition 2.4-4 that the COL or CP applicant will be required to locate any safety-related facility at an elevation above the maximum water surface elevation produced by local intense precipitation (PMP) expected on the ESP site. Since the plant grade has not yet been determined, and its detailed design is beyond the scope of an ESP review, the staff has determined that it is not necessary to impose DSER Permit Condition 2.4-4. The staff will review flooding protection measures based on applicable NRC regulations and regulatory guidance if an application is submitted referencing any ESP that might be issued. Any COL or CP applicant should show that all safety-related structures are located at elevations above the maximum water surface elevation produced by local intense precipitation, or that adequate flood protection measures are in place to ensure their safety. This is **COL Action Item 2.4-5.**

2.4.2.4 Conclusions

As set forth above, the applicant has provided sufficient information pertaining to floods. Therefore, the staff concludes that the applicant has met the requirements relating to floods with respect to 10 CFR 52.17(a) and 10 CFR 100.20(c).

2.4.3 PMF on Streams and Rivers

2.4.3.1 Technical Information in the Application

According to the applicant, the watershed draining into Lake Anna is approximately 323 mi^2 in area. The area of Lake Anna, including the WHTF, is approximately 20 mi^2. Flooding in the watershed would lead to increased water surface level in Lake Anna.

The applicant adhered to the six-subsection format outlined in RG 1.70. Accordingly, the staff's summary of the applicant's methods and findings, discussed below, will also follow this format.

<u>Probable Maximum Precipitation</u>

The applicant stated in SSAR Section 2.4.3.1 that the watershed drainage is 343 mi^2, including the surface area of Lake Anna and the WHTF. The applicant estimated PMP according to procedures outlined in Hydrometeorological Reports (HMRs) 51 ("Probable Maximum Precipitation Estimates. United States East of the 105th Meridian," NOAA, June 1978), 52, and 53 ("Seasonal Variation of 10-Square-Mile Probable Maximum Precipitations Estimates. United States East of the 105th Meridian," NOAA, April 1980). The applicant temporally distributed the 72-hour PMP storm according to guidelines in HMR 52 and ANS/ANSI-2.8-1992, "American National Standard for Determining Design Basis Flooding at Power Reactor Sites," issued 1992. To analyze the PMF runoff, the applicant used an antecedent 72-hour storm equivalent to 40 percent of the PMP, followed by 3 dry days, followed by the full 72-hour PMP storm.

Precipitation Losses

The applicant stated in SSAR Section 2.4.3.2 that it calibrated the precipitation loss parameters in the Hydrologic Engineering Center (HEC) watershed modeling code, HEC-1, using historical storms. The applicant adjusted these losses to minimize differences between observed and simulated rainfall runoff relationships for the basin. The applicant investigated the historical storms used in a 1976 study and three additional storms that occurred in February 1979, March 1994, and June 1995. The applicant selected these additional storms because they produced high water levels in Lake Anna.

Runoff and Stream Course Models

The applicant stated in SSAR Section 2.4.3.3 that it used HEC-1 to estimate runoff and to route the resulting flood through Lake Anna. The applicant then compared the HEC-1 computed discharge and reservoir stages to observed values. The applicant adjusted both base flow and precipitation losses to minimize differences between observed and simulated values, and it used HEC-1 to route the flood through the reservoir with a level pool routing procedure. The analysis treated Lake Anna, including the WHTF, as a single reservoir when the water surface was above 253.5 ft MSL, corresponding to the top of the dikes separating the WHTF from Lake Anna. The analysis neglected any potential storage in the WHTF when the reservoir water surface was below 253.5 ft MSL.

PMF Flow

The applicant estimated peak PMF inflow to Lake Anna in SSAR Section 2.4.3.4 as 302,100 cfs. It estimated the peak discharge over the North Anna Dam to be 141,000 cfs. The applicant also stated that no other dams exist upstream of the North Anna Dam, except two small reservoirs in the drainage area. The applicant did not include the effects of releases from these two small reservoirs in the PMF flow estimation.

Water Level Determinations

The applicant routed the PMF through the reservoir using an HEC-1 level pool routing procedure. The applicant stated in SSAR Section 2.4.3.5 that the maximum water level estimated at the dam is 264.07 ft MSL. The applicant also stated that the resulting backwater profile at the ESP site would be approximately 0.2 ft higher than the water level at the dam. Therefore, the applicant's maximum estimated PMF water surface elevation at the ESP site is 264.27 ft MSL.

Coincident Wind Wave Activity

The applicant stated in SSAR Section 2.4.3.5 that it based the wave setup, added to the PMF-estimated water surface elevation at the ESP site, on a 2-year wind, and that it used a wind speed over ground of 56.0 mi/hr. The applicant estimated maximum and effective fetch lengths[3] to be 10,600 ft and 4,700 ft, respectively. Based upon the values of these parameters,

---

[3] Fetch length is the horizontal distance (in the direction of the wind) over which a wind generates seas or creates a wind setup. On reservoirs and smaller bodies of water, wind setup

the applicant estimated a significant wave height[4] of 2.15 ft, a maximum wave height of 3.60 ft, a wind setup value of 0.09 ft, and a wave runup[5] value of 3.03 ft. The applicant reported the maximum PMF water surface elevation at the ESP site, including wind setup and wave runup, to be 267.39 ft MSL.

The staff requested, in RAI 2.4.3-1, that the applicant provide a calibrated unit hydrograph, expressed in terms of input parameters for HEC-1, from an adjacent unregulated basin of a size similar to the Lake Anna watershed or explain why such a hydrograph is not necessary. In its response, the applicant stated that it based the unit hydrograph it developed for Lake Anna on actual rainfall data and observed water level and discharge data measured at the North Anna Dam. The applicant stated that because this unit hydrograph is based on actual observed responses in the basin, it is more representative of the Lake Anna rainfall-runoff response than that of an adjacent unregulated basin. The applicant also provided definitions of the parameters of the Clark Synthetic Unit Hydrograph and described how the presence of Lake Anna in the drainage area affects these parameters.

The staff requested, in RAI 2.4.3-2, that the applicant provide the supporting input files and the software version information that it used to generate the results discussed in this section. In its response, the applicant provided four HEC-1 input files that it used to determine the watershed runoff hydrograph, perform flood routing, and determine lake water levels. The applicant stated that it used Version 4.0.1E of the HEC-1 computer program for these analyses.

2.4.3.2 Regulatory Evaluation

Section 1.8 of the SSAR presents a detailed discussion of the applicant's conformance to NRC regulations and regulatory guidance. The applicant identified the applicable regulations as 10 CFR 52.17(a)(1)(vi) and 10 CFR 100.20(c) and the applicable regulatory guidance as RGs 1.29, 1.59, 1.70, and 1.102, as well as RS-002. The staff reviewed this portion of the application for conformance with the applicable regulations, and considered the corresponding regulatory guidance, as identified above.

Section 2.4.3 of RS-002 provides the following review guidance used by the staff in evaluating this SSAR section.

Acceptance criteria for this section address 10 CFR Parts 52 and 100, as they relate to identifying and evaluating the hydrologic features of the site. The regulations at 10 CFR

---

is the vertical rise in the still water level on the leeward side of a body of water caused by wind stresses on the surface of the water. Wind setdown is a similar effect, resulting in lowering of the water level. (USACE 2003).

[4] Significant wave height is a statistical term relating to the highest one-third of waves of a given wave group and defined by the average of their heights and periods. The composition of the highest waves depends upon the extent to which the lower waves are considered.

[5] Wave runup is the upper level reached by a wave on a beach or coastal structure, relative to the still water level.

Parts 52 and 100 require that a site's physical characteristics (including seismology, meteorology, geology, and hydrology) be taken into account when determining the acceptability of a site for a nuclear reactor or reactors.

To satisfy the hydrologic requirements of 10 CFR Parts 52 and 100, the SSAR should contain a description of the hydrologic characteristics of the site and region and an analysis of the PMF. This description should be sufficient to assess the acceptability of the site and the potential for those characteristics to influence the design of SSCs important to safety for a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the proposed site. Meeting this guidance provides reasonable assurance that any hydrologic phenomena of severity up to and including the PMF would pose no undue risk to the type of facility proposed for the site.

For those cases in which a reactor design is not specified, the ESP applicant may instead provide a PPE to characterize a facility or facilities for comparison with the hydrologic characteristics of the site. A PPE can be developed for a single type of facility or a group of candidate facilities by selecting limiting values of the relevant parameters.

To determine whether the applicant met the requirements of the hydrologic aspects of 10 CFR Parts 52 and 100, the staff used the following specific criteria.

The PMF, as defined in RG 1.59, has been adopted as one of the conditions to be evaluated in establishing the applicable maximum stream and river flooding level. PMF estimates are needed for all adjacent streams or rivers and site drainage (including the consideration of PMP on the roofs of safety-related structures). The criteria for accepting the applicant's PMF-related design basis depend on one of the following three conditions:

(1) The elevation attained by the PMF (with coincident wind waves) establishes a minimum protection level for use in the design of the facility.

(2) The elevation attained by the PMF (with coincident wind waves) is not controlling; the minimum flood protection level is established by another flood phenomenon (e.g., the probable maximum hurricane (PMH)).

(3) The site is "dry"; that is, the site is well above the elevation attained by a PMF (with coincident wind waves).

When condition 1 is applicable, the staff will assess the flood level. The assessment may be made independently from basic data, by detailed review and checking of the applicant's analyses, or by comparison with estimates made by others that have been reviewed in detail. The applicant's estimates of the PMF level and the coincident wave action are acceptable if the estimates are no more than 5 percent less conservative than the staff estimates. If the applicant's estimates of discharge are more than 5 percent less conservative than the staff's, the applicant should fully document and justify its estimates or accept the staff estimates.

When condition 2 or 3 applies, the staff analyses may be less rigorous. For condition 2, acceptance is based on the protection level estimated for another flood-producing phenomenon exceeding the staff estimate of PMF water levels. For condition 3, the site grade should be well above the staff assessment of PMF water levels. The evaluation of the adequacy of the margin (difference in flood and site elevations) is generally a matter of engineering judgment. The judgment is based on the confidence in the flood-level estimate and the degree of conservatism in each parameter used in the estimate.

The staff used the appropriate sections of several documents to determine the acceptability of the applicant's data and analyses. RG 1.59 provides guidance for estimating the PMF. Publications of NOAA and USACE may be used to estimate PMF discharge and water level condition at the site, as well as coincident wind-generated wave activity.

2.4.3.3 Technical Evaluation

The staff's evaluation consisted of the following independent analysis to verify the applicant's PMF analysis. The staff completed this evaluation in accordance with RS-002.

Probable Maximum Precipitation

The staff determined the PMP using HMRs 51 and 52 and ANSI/ANS-2.8-1992. HMR 51 gives a set of charts of PMP depths for durations of 6, 12, 24, 48, and 72 hours, corresponding to drainage areas of 10, 200, 1,000, 5,000, 10,000, and 20,000 mi^2. Using these charts, the staff determined PMP depths (in inches) for drainage areas of 10, 200, 1000, and 5000 mi^2 for all of the above-stated durations (Table 2.4.3-1).

Using the values in Table 2.4.3-1, the staff prepared depth-area-duration curves following the guidelines of HMR 51 to bracket the drainage area of Lake Anna. Figure 2.4.3-1 illustrates these depth-area-duration curves. The staff determined PMP depth values corresponding to the North Anna Dam drainage area of 343 mi^2 from Figure 2.4-1 to construct Table 2.4.3-2.

Table 2.4.3-1 Probable Maximum Precipitation Values for the North Anna Dam Drainage Area

Area (mi^2)	Duration (hr)				
	6	12	24	48	72
10	28.6	33.4	37.0	41.0	42.8
200	19.8	23.6	28.0	31.7	33.5
1000	14.6	18.5	23.8	26.0	27.0
5000	8.8	12.1	15.5	19.3	20.3

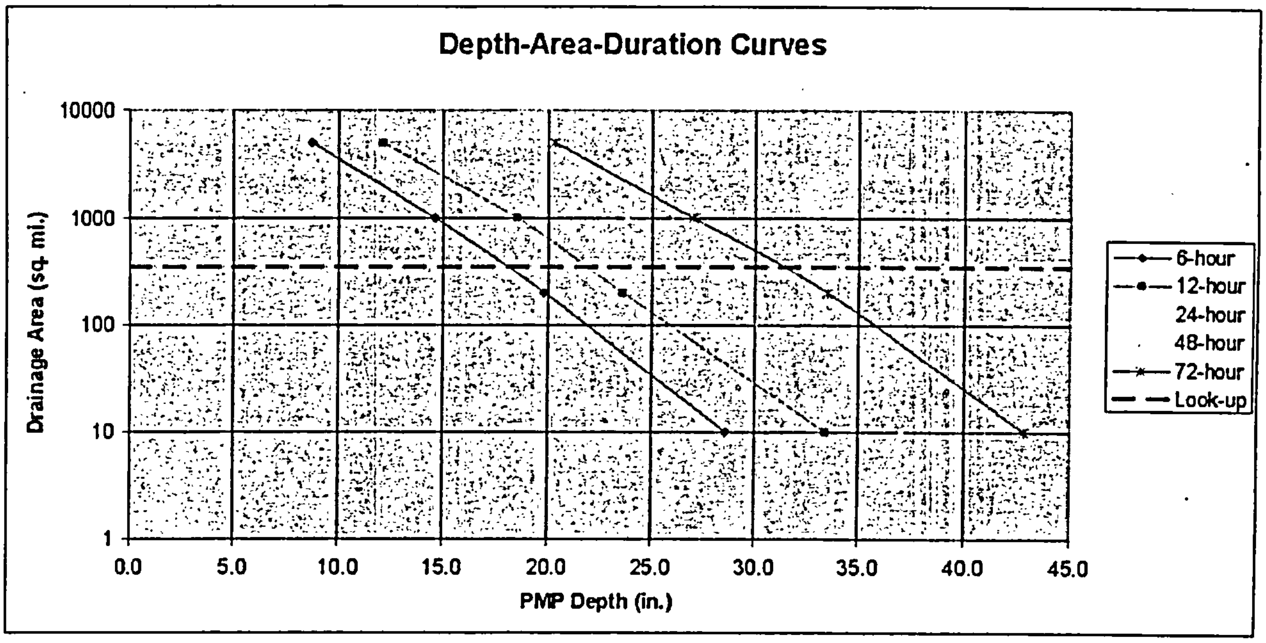


Figure 2.4.3-1 Depth-area-duration curves prepared for bracketing North Anna drainage area. The dotted horizontal line corresponds to a drainage area of 343 mi², equal to that of the North Anna Dam.

Table 2.4.3-2 PMP Depth-Duration Values for the North Anna Dam Drainage Area

	Duration (hr)				
	6	12	24	48	72
North Anna PMP (343 mi²)	18.2	22.0	26.6	30.0	31.2

HMR 52 and ANSI/ANS-2.8-1992 provide guidelines for distributing the PMP depths in time to create a storm sequence during the PMP event. Following these guidelines, the staff computed incremental PMP depths corresponding to all 6-hour durations during the 72-hour PMP (column 2 of Table 2.4.3-3). The incremental depths were grouped into three 24-hour periods in descending order (column 3). The staff rearranged the PMP depths within each 24-hour group according to the guidelines of ANSI/ANS-2.8-1992 (column 4). Finally, the staff rearranged column 4 following the guidelines of ANSI/ANS-2.8-1992 to create the time distribution of the PMP storm over the North Anna Dam drainage area (column 5).

Table 2.4.3-3. Time Distribution of PMP for the North Anna Dam Drainage

6-hr period	Depth (in.)	Group No.	ANSI/ANS-2.8-1992 Rearrange	Time Distribution for PMP (in.)	Time (hr)
1	18.20	1	2.30	0.85	6
2	3.80		3.80	0.85	12
3	2.30		18.20	0.85	18
4	2.30		2.30	0.85	24
5	0.85	2	0.85	2.30	30
6	0.85		0.85	3.80	36
7	0.85		0.85	18.20	42
8	0.85		0.85	2.30	48
9	0.30	3	0.30	0.30	54
10	0.30		0.30	0.30	60
11	0.30		0.30	0.30	66
12	0.30		0.30	0.30	72

Precipitation Losses

The staff assumed that no precipitation losses occurred in order to maximize the flood generated by the PMP storm over the North Anna Dam drainage area.

Runoff and Stream Course Models

The staff conservatively estimated runoff by assuming that the drainage instantaneously discharged to Lake Anna. Under this assumption, the staff estimated the runoff corresponding to all 6-hour durations by multiplying the PMP depth corresponding to that 6-hour duration by the area of the North Anna Dam drainage, and converting the volume of runoff into discharge. Table 2.4.3-4 depicts the PMF thus obtained for the North Anna Dam drainage.

Table 2.4.3-4 PMF into Lake Anna

Time (hr)	Runoff (in.)	Runoff (cfs)
6	0.85	31,358
12	0.85	31,358
18	0.85	31,358
24	0.85	31,358
30	2.3	84,851
36	3.8	140,188
42	18.2	671,426
48	2.3	84,851
54	0.3	11,067
60	0.3	11,067
66	0.3	11,067
72	0.3	11,067

PMF Flow

Table 2.4.3-4, above, presents the staff's estimates of the PMF for the North Anna Dam drainage.

Preliminary Water Level Determinations

The staff followed two approaches to independently and conservatively bracket water levels at the ESP site during the PMF. The first approach was to compute reservoir levels under a steady inflow equal to the applicant's peak PMF discharge (302,100 cfs). The staff conservatively assumed a discharge capacity for each of three spillways of the North Anna Dam as 40,000 cfs. Under the steady inflow scenario, once the spillways reach their discharge capacity, the reservoir would fill and then overtop.

The staff estimated the overtopping flow that must pass over the crest of the dam to be 182,100 cfs. Under these conditions, the staff assumed the full width of the North Anna Dam to act like a weir and estimated the height of flow passing over it using the following wide rectangular weir equation (Chow, *Open Channel Hydraulics*, 1959)—discharge per unit width is $q = CH^{3/2}$, where C is a coefficient ranging from 2.67 to 3.05, and H is the height of flow passing over the weir. The staff obtained values of H corresponding to the two extreme values of C, assuming the dam width is equal to 5,000 ft. Hence, the staff-estimated conservative value of H is 5.71 ft.

The staff estimated the corresponding water level to be 270.71 ft MSL. This value is close to the plant grade. A further increase of water level caused by wind wave runup, surges, and seiche would result in flooding of the ESP site. However, the staff determined that the assumption of steady inflow equal to the applicant's peak PMF discharge was overly conservative because the lake attenuates the time between the steady inflow and the peak PMF discharge.

The next approach the staff used was to route the staff-estimated PMF (column 3 of Table 2.4.3-4), assuming no precipitation loss and instantaneous translation, through Lake Anna using level pool routing (Linsley, et al., *Hydrology for Engineers*, 1982, p. 272). .This second approach resulted in the reservoir inflow-outflow sequence shown in Figure 2.4.3-2. Figure 2.4.3-3 depicts the corresponding reservoir elevations. The staff used the following reservoir operation rules during the PMF event—(1) operate the spillway gates, if reservoir elevation is at 250 ft MSL, to let all inflow pass through, and (2) raise reservoir gates gradually when reservoir elevation exceeds 250 ft MSL to allow more discharge, depending on the reservoir elevation, until water is freely discharged over the spillways.

The staff estimated the maximum reservoir elevation during the PMF event to be 269.13 ft MSL. A further increase of water elevation caused by wind wave runup, surges, and seiche would result in flooding of the ESP site. However, as previously stated, the staff determined that the level pool routing of the staff-estimated North Anna Dam drainage PMF was too conservative because the lake attenuates the time between the steady inflow and the peak PMF discharge.

Because the preliminary analysis did not take into account the delaying effect of Lake Anna for the arrival of the peak PMF flow at the ESP site, the staff used the input data for the HEC-1 analysis from the applicant to independently estimate floodwater level at the ESP site, as discussed below.

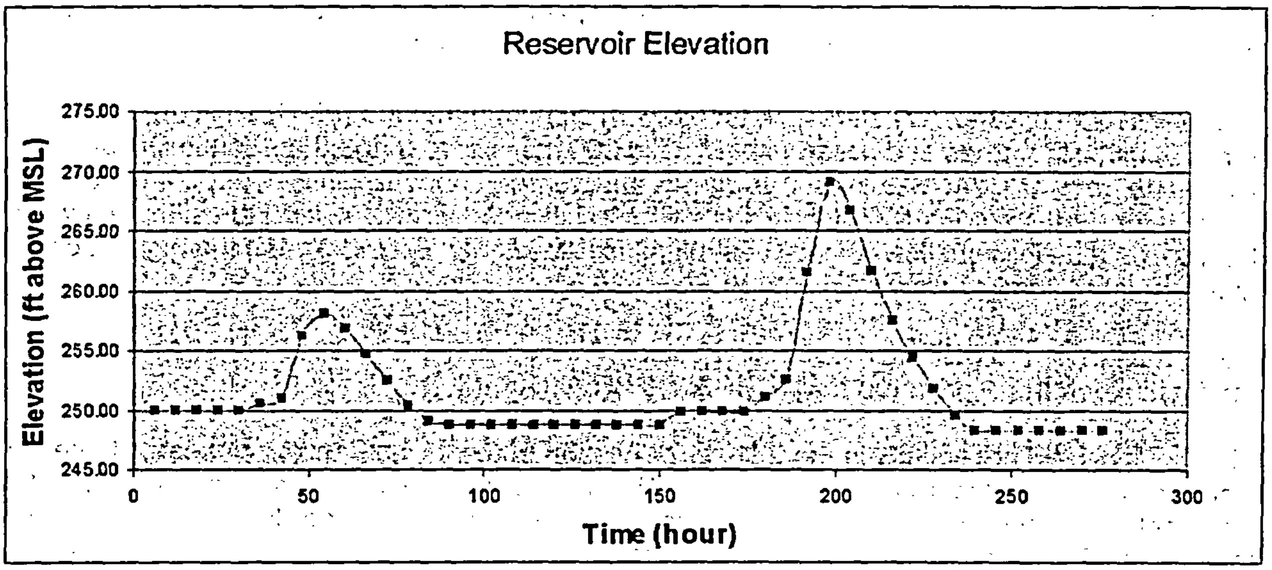


Figure 2.4.3-2 Inflow and outflow hydrographs for North Anna reservoir during the PMF event

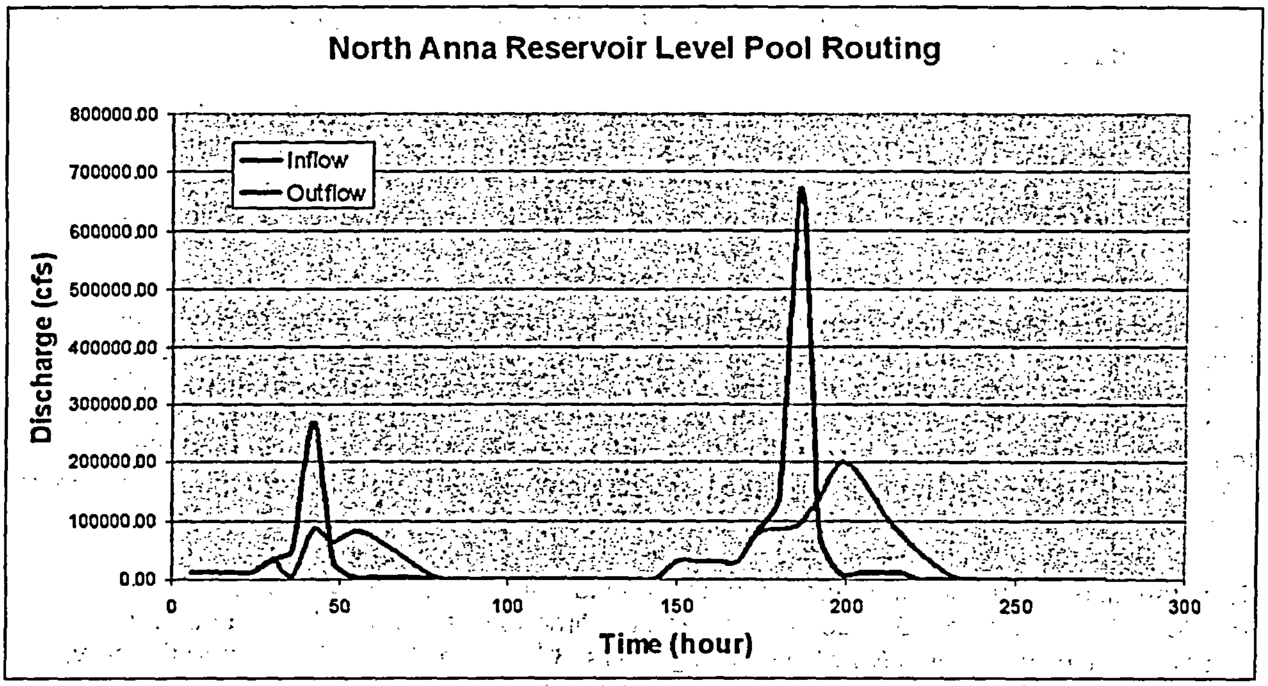


Figure 2.4.3-3 Reservoir elevation during the PMF event

Coincident Wind Wave Activity

The staff estimated wave heights based upon wave height nomographs (see USACE, "Coastal Engineering Manual," EM 1110-2-1100, Revision 1, 2003). These nomographs estimate wave height based upon fetch length and wind speed. The staff used a fetch length of 10,560 ft.

ANSI/ANS-2.8-1992 (p. 17) states, "A probable maximum hurricane (PMH) shall be considered for U.S. coastline areas and areas within 100 to 200 miles bordering...the Atlantic Ocean...." Guidance from ANSI/ANS-2.8-1992 suggests that, for the Great Lakes Region, the maximum over-water wind speed is 100 mi/hr. The staff used this conservative value to estimate a wave height of 4.3 ft. This shallow-water wave height is based upon an average of the highest one-third of representative waves.

Section 2.4.5 of this SER discusses wind setup. Based upon a wind speed of 100 mi/hr, the staff estimated the wind setup for the ESP site to be 0.46 ft.

The applicant did not specify in the SSAR the location of the lowest (and/or closest to Lake Anna) safety-related facility of the ESP site. The staff requested this information in RAI 2.4.1-1. The applicant responded by providing a revised site layout plan with coordinate grids. In order to meet the PPE constraints on ground water level and the site ground water level, the staff intended to constrain the locations of the proposed units toward the northeast corner of the proposed footprint in DSER Permit Condition 2.4-12. The staff determined that it is unnecessary to impose DSER Permit Condition 2.4-12 since it will review and evaluate any future plant design in accordance the NRC regulations to ensure adequate safety during design, construction, or inspection activities for a new plant. Refer to Section 2.4.12 of this SER for additional details.

In response to RAI 2.4.3-1, the applicant provided the details of its input for the HEC-1 analysis. The staff conducted its HEC-1 runs using the applicant's data for routing the PMF through Lake Anna. As described below, the staff determined that the maximum water surface elevation caused by PMF, wind setup, and wave runup is 1.5 ft below the plant grade, which is 271 ft MSL.

The staff's preliminary, highly simplified bounding estimate of water level exceeded the proposed ESP site grade. Therefore, the staff needed to review the applicant's HEC-1 calculations. The applicant provided the staff the HEC-1 input file it used in the calculations. The staff repeated the HEC-1 run using the applicant's input file and the newer Version 4.1 of the HEC-1 software, issued June 1998. The staff determined that the maximum inflow into the lake was 302,953 cfs. The peak outflow from the dam was 141,246 cfs, and the corresponding water surface elevation in the lake was 264.1 ft MSL.

The staff also determined that, for computing floods from PMP, unit hydrograph flood peaks should be increased from 5 to 20 percent, and the time to peak should be reduced by 33 percent (Linsley, et al., *Hydrology for Engineers,* 3rd Edition, 1982; Pilgrim and Cordery, "Flood Runoff," Chapter 9 in *Handbook of Hydrology,* 1992). The staff adjusted the applicant's unit hydrograph according to these guidelines to provide a more conservative estimate of the unit hydrograph than that used by the applicant. Figure 2.4.3-4 illustrates the staff's conservative and the applicant's original unit hydrographs. The peak discharge in staff's conservative unit hydrograph is 20 percent greater than that in applicant's unit hydrograph, and the time to peak in staff's conservative unit hydrograph is reduced by 50 percent compared to that in applicant's unit hydrograph.

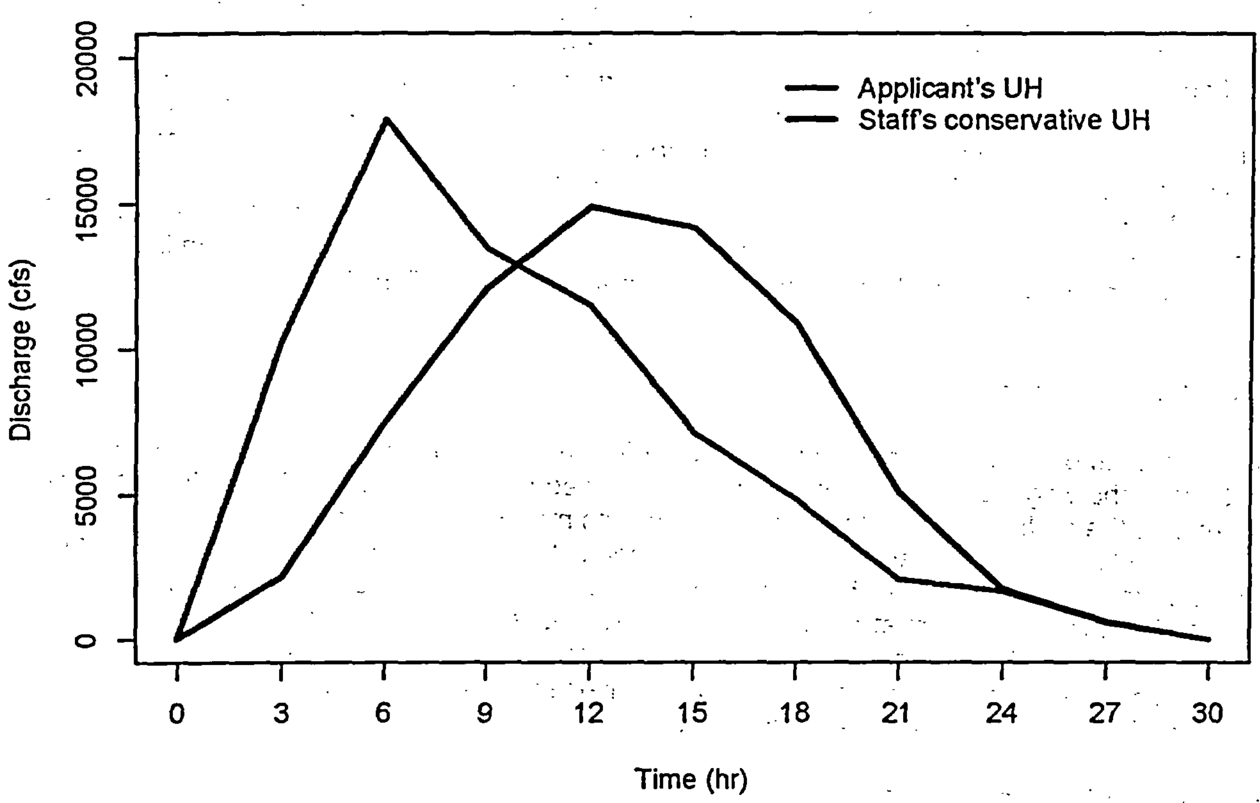


Figure 2.4.3-4 Applicant's original (black line) and staff's conservative (red line) unit hydrographs

The staff also conservatively assumed that no infiltration losses occurred during the PMP event. The staff modified the applicant's HEC-1 input file and carried out another HEC-1 run using the conservative unit hydrograph and no infiltration loss. This run resulted in a peak inflow of 342,502 cfs and a corresponding peak discharge of 143,775 cfs. The maximum calculated water surface elevation at the dam was 264.6 ft MSL.

The staff estimated the maximum water surface elevation at the ESP site by adding wave height (4.3 ft) and wind setup (0.46 ft) to the maximum water surface elevation at the dam (264.6 ft MSL). The staff estimated the maximum water surface elevation at the ESP site to be 269.5 ft MSL. This conservatively estimated maximum water surface elevation at the ESP site is 1.5 ft below the plant grade.

Two small lakes exist upstream from Lake Anna. Lake Louisa was formed by the construction of Louisa Dam on Hickory Creek in 1960, and Lake Orange was formed by the construction of Lake Orange Dam on Clear Creek in 1964. The combined capacity of these two lakes is 7671 ac-ft, approximately equal to 3 percent of Lake Anna's storage capacity between the normal pool and the top of the North Anna Dam. In Section 2.4.4 of this SER, the staff estimates that an increase in inflow volume of 7671 ac-ft to Lake Anna would result in an increase of 0.9 ft in water surface elevation, if the starting elevation were 250 ft MSL. The water surface elevation would increase 0.5 ft, if the starting water surface elevation were 265 ft MSL. Therefore, the staff estimated the water surface elevation corresponding to the PMF, coincident wind wave action, and breach of Lakes Louisa and Orange to be 270 ft MSL. The staff concluded from this information that the maximum water surface elevation caused by the PMF and the coincident wind effects will not result in flooding of the ESP site. The staff's estimate of the PMF level is slightly higher than the applicant's (270 ft MSL vs 267.39 ft MSL). Pursuant to 10 CFR 52.24, the staff is proposing the maximum elevation of ground water at 270 ft MSL or 1 ft below the free surface, whichever is higher, the flood elevation at 270 ft MSL, and the minimum lake water level at 242 ft MLS as site characteristics for inclusion in any ESP that might be issued for the North Anna site. Appendix A of this SER lists the site characteristics.

2.4.3.4 Conclusions

As set forth above, the applicant has provided information pertaining to the PMF on streams and rivers showing that the PMF is below the proposed grade of the ESP PPE (site footprint). Therefore, the staff concludes that the applicant has met the requirements relating to the effects of PMF on streams and rivers, with respect to 10 CFR 52.17(a) and 10 CFR 100.20(c). Further, for the reasons set forth above, the staff concludes that the applicant has considered, in establishing the minimum stream and river flood level acceptable for design purposes, the most severe natural phenomena that have been historically reported for the site and surrounding area with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.4 Potential Dam Failures

2.4.4.1 Technical Information in the Application

The ESP site is located adjacent to Lake Anna and is approximately 5 miles upstream of the North Anna Dam. Lake Anna was created to supply water to the existing NAPS and would be the cooling water and primary service water source for the proposed North Anna Unit 3. The applicant intends to use a dry, closed-cycle cooling system for the proposed Unit 4 which would not withdraw significant amounts of water from the lake for cooling. The UHS for the proposed units would consist of a mechanical draft cooling tower over a buried water storage basin or other passive water storage facility, as called for by the reactor design. The UHS would also provide water for the service water system in the event that the primary source becomes unavailable.

The applicant stated that no other significant dams exist on the North Anna River, either upstream or downstream of the ESP site. The only impoundments in the area are small farm ponds and two small recreational lakes (Lake Louisa and Lake Orange). The applicant concluded that failure of either of these lakes would not produce any measurable effect on Lake Anna, the North Anna Dam, or any safety-related system.

The applicant concluded that the UHS design ensures adequate water for emergency cooling, even if Lake Anna were to be drained as a result of a dam failure. The applicant also concluded that no safety-related structures or systems would be adversely affected by the loss of water caused by a dam failure.

The staff requested, in RAI 2.4.4-1, that the applicant document impounded volumes and the locations of Lake Louisa and Lake Orange relative to Lake Anna. The staff also requested that the applicant provide its methodology for documenting failure of dams on these lakes. In its response, the applicant stated that Lake Louisa is located on Hickory Creek, a tributary to the North Anna River, and Lake Orange is located on Clear Creek, a tributary to Pamunkey Creek, which is a tributary to Lake Anna. Lake Louisa is located approximately 3.4 miles upstream of Lake Anna. It has a surface area of 280 ac, and a storage volume of 4713 ac-ft. Lake Orange is located approximately 8.8 miles upstream of Lake Anna. It has a surface area of 120 ac, and a storage volume of 2958 ac-ft. The applicant stated that the storage capacity of Lake Anna between the normal water surface elevation of 250 ft MSL and the top of the dam elevation of 265 ft MSL is 245,000 ac-ft. This storage capacity of Lake Anna is sufficient to accommodate the combined storage capacity of the two recreational lakes, which is equal to 7671 ac-ft. The applicant also considered the scenario in which dams on both Lake Louisa and Lake Orange fail during a PMP event, such that the discharge from these dam breaches arrives at Lake Anna at the same time as the peak discharge of the PMF generated by the PMP event on Lake Anna's watershed. The applicant estimated that the additional increase in PMF peak water surface elevation caused by these dam breaches would be 0.4 ft. The applicant concluded that the resulting water surface elevation would be 264.67 ft MSL, which is below the proposed site grade of 271 ft MSL. (The staff considers such an effect in Section 2.4.3.3 of this SER.)

The staff requested, in RAI 2.4.4-2, that the applicant provide details regarding storage capacity and design parameters for this underground basin. In its response, the applicant stated that a mechanical draft cooling tower over an underground basin would be used as the UHS, if the selected plant design includes a UHS. A separate cooling tower and basin would be provided for each proposed unit. The storage volume for each basin would be 4,090,625 ft^3, and each basin would be approximately 235 ft wide, 350 ft long, and 50 ft deep. The applicant stated that additional basin depth will be provided for freeboard and to accommodate a possibly frozen surface layer.

2.4.4.2 Regulatory Evaluation

Section 1.8 of the SSAR presents a detailed discussion of the applicant's conformance to NRC regulations and regulatory guidance. The applicant identified the applicable regulations as 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.23(c), and the applicable regulatory guidance as RGs 1.29, 1.59, 1.70, and 1.102, as well as RS-002. The staff reviewed this portion of the application for conformance with the applicable regulations, and considered the corresponding regulatory guidance, as identified above.

Section 2.4.4 of RS-002 provides the review guidance discussed below and used by the staff in evaluating this SSAR section.

Acceptance criteria for this section are based on meeting the requirements of the following regulations:

- 10 CFR Parts 52 and 100, as they relate to evaluating hydrologic features of the site

- 10 CFR 100.23, "Geologic and Seismic Siting Criteria," as it relates to establishing the design-basis flood resulting from seismic dam failure

The regulations at 10 CFR 52.17(a) and 10 CFR 100.20(c) require that the site's physical characteristics (including seismology, meteorology, geology, and hydrology) be taken into account when determining its acceptability to host a nuclear reactor or reactors.

The regulations at 10 CFR Parts 52 and 100 are applicable to SSAR Section 2.4.4 because they address the physical characteristics, including hydrology, considered by the Commission when determining the acceptability of a site for a power reactor. To satisfy the hydrologic requirements of 10 CFR Parts 52 and 100, the SSAR should contain a description of the hydrologic characteristics of the region and an analysis of potential dam failures. The description should be sufficient to assess the acceptability of the site and the potential for those characteristics to influence the design of SSCs important to safety. Meeting this criterion provides reasonable assurance that the effects of high water levels resulting from failure of upstream dams, as well as those of low water levels resulting from failure of a downstream dam, would pose no undue risk to the type of facility proposed for the site.

For those cases in which a reactor design is not specified, the ESP applicant may instead provide a PPE to characterize a facility or facilities for comparison with the hydrologic characteristics of the site. A PPE can be developed for a single type of facility or a group of candidate facilities by selecting limiting values of relevant parameters.

The regulation at 10 CFR 100.23 requires consideration of geologic and seismic factors in determining site suitability. Specifically, 10 CFR 100.23(c) requires an investigation of the geologic and seismic site characteristics to permit evaluation of seismic effects on the site. Such an evaluation will consider seismically induced floods, including failure of an upstream dam during an earthquake.

The regulation at 10 CFR 100.23 is applicable to SSAR Section 2.4.4 because it requires investigation of seismic effects on the site. Such effects include seismically induced floods or low water levels, which constitute one element in the Commission's consideration of the suitability of proposed sites for nuclear power plants. RG 1.70 provides more detailed guidance on the investigation of seismically induced floods, including results for seismically induced dam failures and antecedent flood flows coincident with the flood peak. Meeting this guidance provides reasonable assurance that, given the geologic and seismic characteristics of the proposed site, a nuclear power plant or plants of a specified type (or falling within a PPE) could be constructed and operated on the proposed site without undue risk to the health and safety of the public, with respect to those characteristics.

The staff used the following criteria to determine whether the applicant met the requirements of 10 CFR Parts 52 and 100 and 10 CFR 100.23, as they relate to dam failures:

- The staff will review the applicant's analyses and independently assess the coincident river flows at the site and at the dams being analyzed. ANSI/ANS-2.8-1992 provides guidance on acceptable river flow conditions to be assumed coincident with the dam failure event. To be acceptable, the applicant's estimates (which may include landslide-induced failures) of the flood discharge resulting from the coincident events should be no more than 5 percent less conservative than the staff estimates. If the applicant's estimates differ by more than 5 percent, the applicant should fully document and justify its estimates or accept the staff estimates.

- The applicant should identify the location of dams and potentially "likely" or severe modes of failure. Dams or embankments for the purpose of impounding water for a nuclear power plant(s) or plants that might be constructed on the proposed site should also be identified. The potential for multiple, seismically induced dam failures and the domino failure of a series of dams should be discussed. Approved models of the USACE and the Tennessee Valley Authority should be used to predict the downstream water levels resulting from a dam breach. First-time use of other models will necessitate complete model description and documentation. The staff will determine the acceptance of the model (and subsequent analyses) based on its review of model theory, available verification, and application. For cases which assume something other than instantaneous failure, the applicant should thoroughly document the conservatism of the rate of failure and shape of the breach. A determination of the peak flow rate and water level at the site for the worst possible combination of dam failures, as well as a summary analysis (that substantiates the condition as the critical permutation) should be presented, along with a description (and the bases) of all coefficients and methods used. In addition, the effects of other concurrent events on plant safety, such as blockage of the river and waterborne missiles, should be considered.

- The effects of coincident and antecedent flood flows (or low flows for downstream structures) on initial pool levels should be considered. Depending upon estimated failure modes and the elevation difference between plant grade and normal river levels, it may be acceptable to use conservative, simplified procedures to estimate flood levels at the site. Where calculated flood levels using simplified methods are at or above plant grade and include assumptions which cannot be demonstrated as conservative, it will be necessary to use unsteady flow methods to develop flood levels at the site. References 7, 13, and 14 of RS-002 are acceptable methods; however, other programs could be acceptable with proper documentation and justification. Computations, coefficients, and methods used to establish the water level at the site for the most critical dam failures should be summarized. Coincident wind-generated wave activity should be considered in a manner similar to that discussed in Section 2.4.3 of RS-002.

RG 1.59 provides guidance for estimating the maximum flooding level, considering the worst single phenomenon and a combination of less severe phenomena.

2.4.4.3 Technical Evaluation

The staff consulted USGS maps to independently verify the applicant's information and concluded that no dams of significant storage, the failure of which could endanger the North Anna Dam, exist upstream.

Using the National Inventory of Dams, the staff independently found that Lake Louisa was formed by the construction of Louisa Dam on Hickory Creek in 1960, and Lake Orange was formed by the construction of Lake Orange Dam on Clear Creek in 1964. The storage capacity of Lake Louisa is 4173 ac-ft and Lake Orange is 2958 ac-ft. The combined capacity of these two lakes is 7671 ac-ft, approximately 3 percent of Lake Anna's storage capacity between the normal pool and the top of the North Anna Dam. The staff estimated that an increase in inflow volume of 7671 ac-ft to Lake Anna would result in an increase of 0.9 ft in water surface elevation, if the starting elevation were 250 ft MSL. The water surface elevation would increase 0.5 ft if the starting water surface elevation were 265 ft MSL. The staff estimated the water surface elevation corresponding to the PMF, coincident wind wave action, and breach of Lakes Louisa and Orange to be 270 ft MSL. The staff concludes that simultaneous arrival of all water stored in these two lakes coincident with the PMF would not result in flooding of the ESP site, which is at an elevation of 271 ft MSL.

In the event of failure of the North Anna Dam, the proposed new nuclear power plants would rely on the UHS for essential cooling, if the selected plant design includes a UHS. The applicant intends to use underground reservoirs for the UHS, which would be approximately 50 ft deep. The maximum elevation of ground water at the proposed site is 270 ft MSL. It is essential for ensuring the integrity of the UHS reservoirs that any uplift of the reservoirs caused by buoyancy, either during construction or during the life of the proposed plants, is precluded. Therefore, the free surface elevation of the UHS may not fall below 270 ft MSL. The staff identified this as DSER Permit Condition 2.4-5.

The applicant in its letter dated March 3, 2005, in response to Open Item 2.4-6, stated that details of the location and construction of the UHS have not been established. If the chosen reactor design calls for a conventional UHS, the design, location, and construction details of the UHS would be determined as part of detailed engineering and described in the COL or CP application. The applicant's response includes a detailed discussion of the engineering feasibility of ensuring that an underground UHS reservoir would be able to rely on the friction resistance from the foundation on the embedded side walls of the reservoir without any vertical uplift of the UHS reservoir because of hydrostatic upward pressure from ground water. The applicant also discussed the potential for use of rock anchors to prevent uplift of the UHS reservoir.

The staff does not endorse any reliance on skin friction between backfill and a structure critical to safety. The foundation is likely to encounter fissured rock and, over a period of 40 to 60 years, could experience considerable shrinkage and cracking, all of which can render side friction ineffective. Uplift resistance has been estimated using a nonnuclear standard (U.S. Department of Transportation, Federal Highway Administration, "Drilled Shafts," Publication No. FHWA-HI-88-042, July 1988) for anchors in fissured rock. The staff does not endorse or accept the applicant's conceptual approach for establishing UHS reservoir stability under buoyancy. However, the staff accepts that a combination of water height limit in the reservoir and an engineered and monitored posttensioned anchorage system can reliably prevent any uplift of the UHS reservoir, should one be needed. A detailed engineering design of the UHS reservoir is not within the scope of the ESP review. Based on the above, the staff has determined that NRC regulations and regulatory guidance will ensure the safety of any future UHS design and construction; therefore the proposed permit condition is not needed for the ESP. Instead, any COL or CP applicant should demonstrate that the UHS reservoirs are designed so as to satisfy the NRC's regulations. A COL or CP applicant may demonstrate compliance by following applicable NRC guidance. This is **COL Action Item 2.4-6.**

In response to RAI 2.4.4-2, the applicant provided details of the UHS, if the selected plant design includes a UHS, for the proposed units and the storage capacity of the associated underground UHS basins. Based on the applicant's dimensions of the underground UHS basin, the staff estimated the storage capacity of the UHS basins to be 4.1 million ft^3. Based on its review of site water availability, the staff intended to specify in DSER Permit Condition 2.4-6 that this estimated UHS basin storage capacity, should the selected plant design include a UHS, as the minimum acceptable storage capacity. Since the selection and detailed design of the plants, including their emergency cooling systems, that may be constructed on the ESP site are beyond the scope of an ESP review, the staff determined that it is not necessary to impose DSER Permit Condition 2.4-6. The staff will perform its review of the design of the plants, including their emergency cooling systems, according to NRC regulations and regulatory guidance. If the selected plant designs include, a UHS, any COL or CP applicant should demonstrate that the UHS storage basins provide storage sufficient to meet 30-day emergency cooling water needs accounting for any and all losses including but not limited to seepage, evaporation, and icing for the selected plants. Programmatic provisions should be provided for plant shut down when the liquid water volume in the UHS storage basin is inadequate. This is **COL Action Item 2.4-7.**

2.4.4.4 Conclusions

As set forth above, the applicant has provided sufficient information pertaining to dam failures. Therefore, the staff concludes that the applicant has met the requirements relating to dam failures, with respect to 10 CFR 52.17(a), 10 CFR 100.20(c), and 10 CFR 100.23(c). The applicant has considered the most severe natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated in establishing the minimum consequences of dam failure acceptable for design purposes.

2.4.5 Probable Maximum Surge and Seiche Flooding

The ESP site is located on the shores of Lake Anna, approximately 50 miles inland from the Chesapeake Bay at an elevation of 271 ft MSL. Lake Anna is a 17-mi-long reservoir formed when the dam was constructed on the North Anna River. The ESP site is located at the approximate longitudinal midpoint of the reservoir, 5 miles upstream of the North Anna Dam.

2.4.5.1 Technical Information in the Application

The applicant stated that the ESP site is not located on an estuary or an open coast and concluded that both surge and seiche flooding would not produce critical water levels at the site. The applicant estimated a maximum fetch length of 10,600 ft. The applicant concluded that, given the relatively short fetch length, surges and waves produced from winds or oscillatory waves alone would not produce water heights greater than the still water level resulting from the PMF.

2.4.5.2 Regulatory Evaluation

Section 1.8 of the SSAR presents a detailed discussion of the applicant's conformance to NRC regulations and regulatory guidance. The applicant identified the applicable regulations as Appendix S to 10 CFR Part 50, 10 CFR 52.17(a), 10 CFR Part 100, and 10 CFR 100.20(c) and the applicable regulatory guidance as RGs 1.29, 1.59, 1.70, 1.102, and 1.125, "Physical Models for Design and Operation of Hydraulic Structures and Systems for Nuclear Power Plants," Revision 1 dated October 1978 as well as RS-002. The staff reviewed the probable maximum surge and seiche flooding portion of the application for conformance with the applicable regulations, and considered the corresponding regulatory guidance, as identified above, except that consideration of Appendix S to 10 CFR Part 50 is limited to the determination of seismically induced floods and water waves pursuant to Section IV(c) of Appendix S.

Section 2.4.5 of RS-002 provides guidance for the staff's evaluation of this SSAR section. This section states that the staff's review is based on determining whether the applicant has met the requirements of 10 CFR Parts 52 and 100, as they relate to evaluating the hydrologic characteristics of the site. Specific criteria necessary to meet the relevant hydrologic requirements of 10 CFR Parts 52 and 100 include the regulations at 10 CFR 52.17(a) and 10 CFR 100.20(c), which require that the site's physical characteristics (including seismology, meteorology, geology, and hydrology) be taken into account when determining its acceptability for a nuclear reactor or reactors.

To satisfy the hydrologic requirements of 10 CFR Parts 52 and 100, the SSAR should contain a description of the surface and subsurface hydrologic characteristics of the region and an analysis of the potential for flooding caused by surges or seiches. This description should be sufficient to assess the acceptability of the site and the potential for a surge or seiche to influence the design of SSCs important to safety for a nuclear power plant or plants of a specified type that might be constructed on the proposed site. Meeting this guidance provides reasonable assurance that the most severe flooding likely to occur as a result of storm surges[6] or seiches would not pose an undue risk to the type of facility proposed for the site.

For those cases in which a reactor design is not specified, the ESP applicant may instead provide a PPE to characterize a facility or facilities for comparison with the hydrologic characteristics of the site. A PPE can be developed for a single type of facility or a group of candidate facilities by selecting limiting values of the relevant parameters.

If it has been determined that surge and seiche flooding estimates are necessary to identify flood design bases, the applicant's analysis will be considered complete and acceptable if the following areas are addressed and can be independently evaluated from the applicant's submission:

- All reasonable combinations of PMH, moving squall line, or other cyclonic wind storm parameters are investigated, and the most critical combination is selected for use in estimating a water level.
- Models used in the evaluation are verified or have been previously approved by the staff.
- Detailed descriptions of bottom profiles are provided (or are readily obtainable) to enable an independent staff estimate of surge levels.

---

[6]A storm surge is a rise above normal water level on the open coast caused by the action of wind stress on the water surface. A storm surge resulting from a hurricane also includes that rise in level caused by atmospheric pressure reduction, as well as that resulting from wind stress (USACE 2003).

- Detailed descriptions of shoreline protection and safety-related facilities are provided to enable an independent staff estimate of wind-generated waves, runup, and potential erosion and sedimentation.

- Ambient water levels, including tides and sea-level anomalies, are estimated using NOAA and USACE publications as described below.

- Combinations of surge levels and waves that may be critical to the design of a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the proposed site are considered, and adequate information is supplied to allow a determination that no adverse combinations have been omitted.

This section of the SSAR may also state with justification that surge and seiche flooding estimates are not necessary to identify the flood design basis (e.g., the site is not near a large body of water).

The staff uses hydrometeorological estimates and criteria issued by USACE and NOAA for developing PMHs for east and Gulf Coast sites, squall lines for the Great Lakes, and severe cyclonic wind storms for all lake sites to evaluate the conservatism of the applicant's estimates of severe windstorm conditions, as discussed in RG 1.59. The USACE and NOAA criteria call for variation of the basic meteorological parameters within given limits to determine the most severe combination that could result. The applicant's hydrometeorological analysis should be based on the most critical combination of these parameters.

The staff uses data from the publications of NOAA, USACE, and other sources (such as tide tables, tide records, and historical lake level records) to substantiate antecedent water levels. These antecedent water levels should be as high as the "10% exceedance" monthly spring high tide, in addition to a sea-level anomaly based on the maximum difference between recorded and predicted average water levels for durations of 2 weeks or longer for coastal locations, or the 100-year recurrence interval high water for the Great Lakes. In a similar manner, the staff independently evaluates storm track, wind fields, effective fetch lengths, direction of approach, timing, and frictional surface and bottom effects to ensure that the applicant has selected the most critical values. The staff verifies models used to estimate surge hydrographs that it has not previously reviewed and approved by modeling historical events, with any discrepancies in the model being on the conservative (i.e., high) side.

The staff uses USACE criteria and methods, as generally summarized in Reference 9 of RS-002, as a standard to evaluate the applicant's estimate of coincident wind-generated wave action and runup. In addition, the staff uses the criteria and methods of the USACE and other standard techniques to evaluate the potential for oscillation of waves at natural periodicity.

2.4.5.3 Technical Evaluation

The staff conducted its review in accordance with Section 2.4.5 of RS-002 and RG 1.59. The ESP site is located 50 miles inland from the nearest body of open water (i.e., the Chesapeake Bay) subject to a storm surge. The ESP site is at an elevation of 271 ft MSL. Therefore, the staff concludes that the ESP site is not subject to a storm surge.

The following describes the staff's independent evaluation to estimate seiche effects. Fetch length is one of the key parameters for determining wind setup, and it is generally based upon the longest straight-line distance to the opposing shore. Although the ESP site is 5 miles from the North Anna Dam and more than 10 miles from the upstream end of the reservoir, the longest straight-line distance to the opposing shore is approximately 2 miles (see Figure 2.4.5-1).

Irregular lake bathymetry and strong thermal stratification that exists during various parts of the year affect wind setup near the ESP site. An accurate estimate of the wind setup that considers all of these complicating factors would require use of a multidimensional hydrodynamic and water quality model.

A simplifying and conservative approach to estimating wind setup is to assume that the lake is not thermally stratified and is represented as a uniform rectangular basin with one side equal to the fetch length. The staff assumed a uniformly distributed wind stress along the water surface, so that the hydrodynamic equations of motion can be simplified and an analytic solution for the surface setup can be obtained. The following is the resulting solution:

$$\varsigma = \frac{CU^2L}{h}$$

where ζ is the wind setup in ft, U is the wind speed in mi/hr, h is the average depth of the lake in ft, L is the fetch length in ft, and C is an empirical coefficient equal to 1.5×10^{-7} (Heaps, "Vertical Structure of Current in Homogeneous and Stratified Waters," in *Hydrodynamics of Lakes,* 1984, pp. 153–207). The staff used a value of 10,560 ft for L. Bathymetry contours (see Figure 2.4.5-1) indicate that the original river level was at an approximate elevation of 200 ft MSL. Since the water depth, h, is in the denominator, a smaller depth would produce a larger (i.e., more conservative) wind setup. However, since wind setup is a relatively minor effect (no more than a few feet), a low initial lake surface elevation would indicate that the wind setup would be unlikely to reach the ESP site elevation and is not reasonable, so a deeper average water depth was chosen based upon the ESP site elevation. Accordingly, the staff used an average water depth of 35 ft.

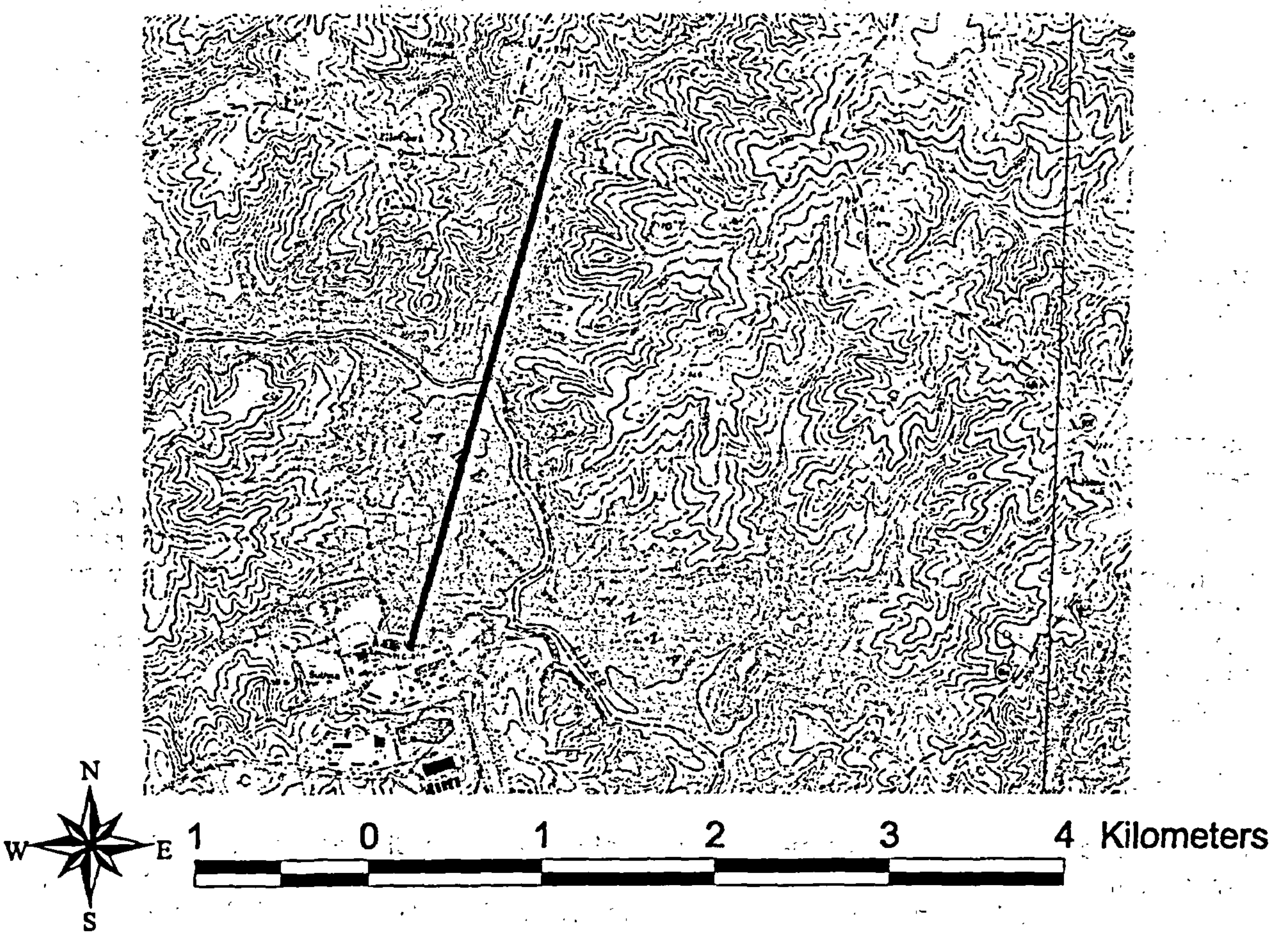


Figure 2.4.5-1 North Anna Power Station site and fetch length

Another parameter in the wind setup equation is wind speed over the water surface. One of the derivation assumptions for the wind setup equation is that the wind speed is steady and uniformly blowing in the direction of maximum fetch. ANSI/ANS-2.8-1992 suggests that, for the Great Lakes region, the maximum over-water wind speed is 100 mi/hr. The staff used this conservative value as the steady over-water wind speed in the wind setup equation.

Using these values, the staff estimated the resulting wind setup as 0.46 ft. The staff combined this increase in water surface elevation at the ESP site with the estimated stage resulting from the PMF, as discussed in Section 2.4.3 of this SER.

The staff estimated the period of oscillation caused by seiche along the fetch length line shown in Figure 2.4.5-1 based on the theory for free oscillation of water of uniform depth in a rectangular basin (Wilson, "Seiches," *Advances in Hydroscience,* Volume 8, 1972):

$$T = \frac{2L}{\sqrt{gh}}$$

where T is the period of seiche motion in seconds, g is the acceleration caused by gravity ($32.2\ ft/s^2$), and L and h are as defined in the equation for wind setup. The staff estimated the resulting seiche period to be approximately 10.5 minutes. This period is significantly shorter than the meteorologically induced wave periods (e.g., synoptic storm pattern frequency and dramatic reversals in steady wind direction necessary for wind setup). Therefore, the staff concludes that meteorologically forced resonance on Lake Anna is not likely.

Overall, the staff concludes that seismically induced seiche is not likely in Lake Anna because of the large difference between the period of oscillation caused by seiche and that of seismically induced vibration.

2.4.5.4 Conclusions

As set forth above, the applicant has provided sufficient information pertaining to surge and seiche. Therefore, the staff concludes that the applicant has met the requirements relating to surge and seiche with respect to 10 CFR 52.17(a), 10 CFR 100.20(c), and Section IV(c) of Appendix S to 10 CFR Part 50. In addition, the seismically induced flooding analysis reflects the most severe seismic event historically reported for the site and surrounding area (with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated). The staff concludes that the applicant partially conforms to GDC 2 in Appendix A to 10 CFR Part 50, insofar as that analysis defines the minimum flood level acceptable for design for seismically induced surge and seiche.

2.4.6 Probable Maximum Tsunami Flooding

The ESP site is located approximately 50 miles inland from the Chesapeake Bay (Potomac River) at an elevation of 271 ft MSL on the shores of Lake Anna, a 17-mi-long reservoir that was formed when the dam was constructed on the North Anna River. The ESP site is approximately 5 miles upstream of the North Anna Dam.

2.4.6.1 Technical Information in the Application

The applicant stated in SSAR Section 2.4.6 that, because the site is at an inland location and not located on an estuary or open coast, tsunami flooding is not a design consideration. The applicant only considered tsunami flooding associated with seismically generated waves in open water that affect coastal areas.

2.4.6.2 Regulatory Evaluation

Section 1.8 of the SSAR presents a detailed discussion of the applicant's conformance to NRC regulations and regulatory guidance. The applicant identified the applicable regulations as 10 CFR 52.17(a), 10 CFR Part 100, 10 CFR 100.20(c), and 10 CFR 100.23(c) and the applicable regulatory guidance as RGs 1.29, 1.59, 1.70, 1.102, and 1.125, as well as RS-002. The staff reviewed this portion of the application for conformance with the applicable regulations, and considered the corresponding regulatory guidance, as identified above.

Section 2.4.6 of RS-002 provides the guidance the staff used in evaluating this SSAR section, which is based on meeting the requirements of the following regulations:

- 10 CFR Parts 52 and 100, as they relate to identifying and evaluating hydrologic features of the site

- 10 CFR 100.23, as it relates to investigating the tsunami potential at the site

The regulations at 10 CFR 52.17(a) and 10 CFR 100.20(c) require that the site's physical characteristics (including seismology, meteorology, geology, and hydrology) be taken into account when determining its acceptability to host a nuclear reactor or reactors. The regulations at 10 CFR Parts 52 and 100 are applicable to SSAR Section 2.4.6 because they address the physical characteristics, including hydrology, considered by the Commission when determining the acceptability of the proposed site. To satisfy the hydrologic requirements of 10 CFR Parts 52 and 100, the SSAR should contain a description of the hydrologic characteristics of the coastal region in which the proposed site is located and an analysis of severe seismically induced waves. The description should be sufficient to assess the acceptability of the site and the potential for a tsunami to influence the design of SSCs important to safety for a nuclear power plant or plants of a specified type that might be constructed on the proposed site. Meeting this guidance provides reasonable assurance that the most severe flooding likely to occur as a result of a tsunami would pose no undue risk to the type of facility proposed for the site.

For those cases in which a reactor design is not specified, the ESP applicant may instead provide a PPE to characterize a facility or facilities for comparison with the hydrologic characteristics of the site. A PPE can be developed for a single type of facility or a group of candidate facilities by selecting limiting values of the relevant parameters.

The regulation at 10 CFR 100.23(c) requires that geologic and seismic factors be considered when determining the suitability of the site. As required by 10 CFR 100.23(c), an investigation of the geologic and seismic site characteristics is conducted to permit adequate evaluation of seismic effects on the site. Such an evaluation will consider seismically induced floods and water waves. This regulation is applicable to SSAR Section 2.4.6 because it requires investigation of seismic effects on the site. Such effects include distantly and locally generated waves or tsunami that have affected or could affect a proposed site, including the runup or drawdown associated with historic tsunami in the same coastal region, as well as local features of coastal topography that might modify runup or drawdown. RG 1.70 provides more detailed guidance on the investigation of seismically induced flooding.

To determine whether the applicant met the requirements of 10 CFR Part 52, 10 CFR Part 100, and 10 CFR 100.23 with respect to tsunami and the analysis thereof, the staff used the following specific criteria:

- If it has been determined that tsunami estimates are necessary to identify flood or low-water design information, the analysis will be considered complete if the following areas are addressed and can be independently evaluated from the applicant's submission:

  — All potential distant and local tsunami generators, including volcanoes and areas of potential landslides, are investigated and the most critical ones are selected.

- The analysis uses conservative values of seismic characteristics (source dimensions, fault orientation, and vertical displacement) for the tsunami generators selected.

- All models used in the analysis are verified or have been previously approved by the staff. RG 1.125 provides guidance on the use of physical models of wave protection structures.

- Bathymetric data are provided (or are readily obtainable).

- Detailed descriptions of shoreline protection and safety-related facilities are provided for wave runup and drawdown estimates. RG 1.102 provides guidance on flood protection for nuclear power plants.

- Ambient water levels, including tides, sea level anomalies, and wind waves, are estimated using NOAA and USACE publications, as described below.

- If the applicant adopts RG 1.59, Regulatory Position 2, the design basis for tsunami protection of all safety-related facilities identified in RG 1.29 should be shown at the COL or CP stage to be adequate in terms of the time necessary for implementing any emergency procedures.

• The applicant's estimates of tsunami runup and drawdown levels are acceptable if the estimates are no more than 5 percent less conservative than the staff estimates. If the applicant's estimates are more than 5 percent less conservative (based on the difference between normal water levels and the maximum runup or drawdown levels) than the staff's, the applicant should fully document and justify its estimates or accept the staff estimates.

• This section of the SSAR will also be acceptable if it states the criteria that the applicant used to determine that tsunami flooding estimates are not necessary to identify the minimum flood level used for design (e.g., the site is not near a large body of water).

2.4.6.3 Technical Evaluation

The staff found during its independent review that, according to NOAA (NOAA, 2004: What was the highest tsunami? Frequently asked questions, Tsunami Research Program website, http://www.pmel.noaa.gov/tsunami/Faq/x005_highest, accessed November 1, 2004), the 10 most destructive tsunami in the Pacific Ocean since 1990 produced maximum wave heights of 9.8 to 49 ft. A wave height of 100 ft was recorded on the coast of Japan during the 1993 Okushiri tsunami. The ESP site is located at an elevation of 271 ft MSL. The staff therefore concluded that the effects of even the largest tsunami in open water would not be high enough to exceed the elevation of the ESP site.

The staff also considered the potential of flooding on the shores of Lake Anna near the ESP site as a result of wave runup caused by a seismically induced hillslope failure. A hypothetical landslide was modeled to examine the potential for the ESP site to be exposed to a seismically induced water wave. The staff's calculation assumed a landslide created by the surrounding hillsides, which are at an approximate elevation of 300 ft MSL. Assuming normal water surface level in Lake Anna, a landslide could therefore fall 50 ft before hitting the water. If drag is neglected, an object falling from the hilltop could reach a vertical speed of approximately 55 ft/s. The staff conservatively assumed that such a hillslope failure might result in a horizontal water wave of the same speed. In addition, the staff conservatively assumed that this landslide would displace water from the existing shoreline to the deepest portion of the lake approximately 70 ft offshore (see Figure 2.4.6-1).

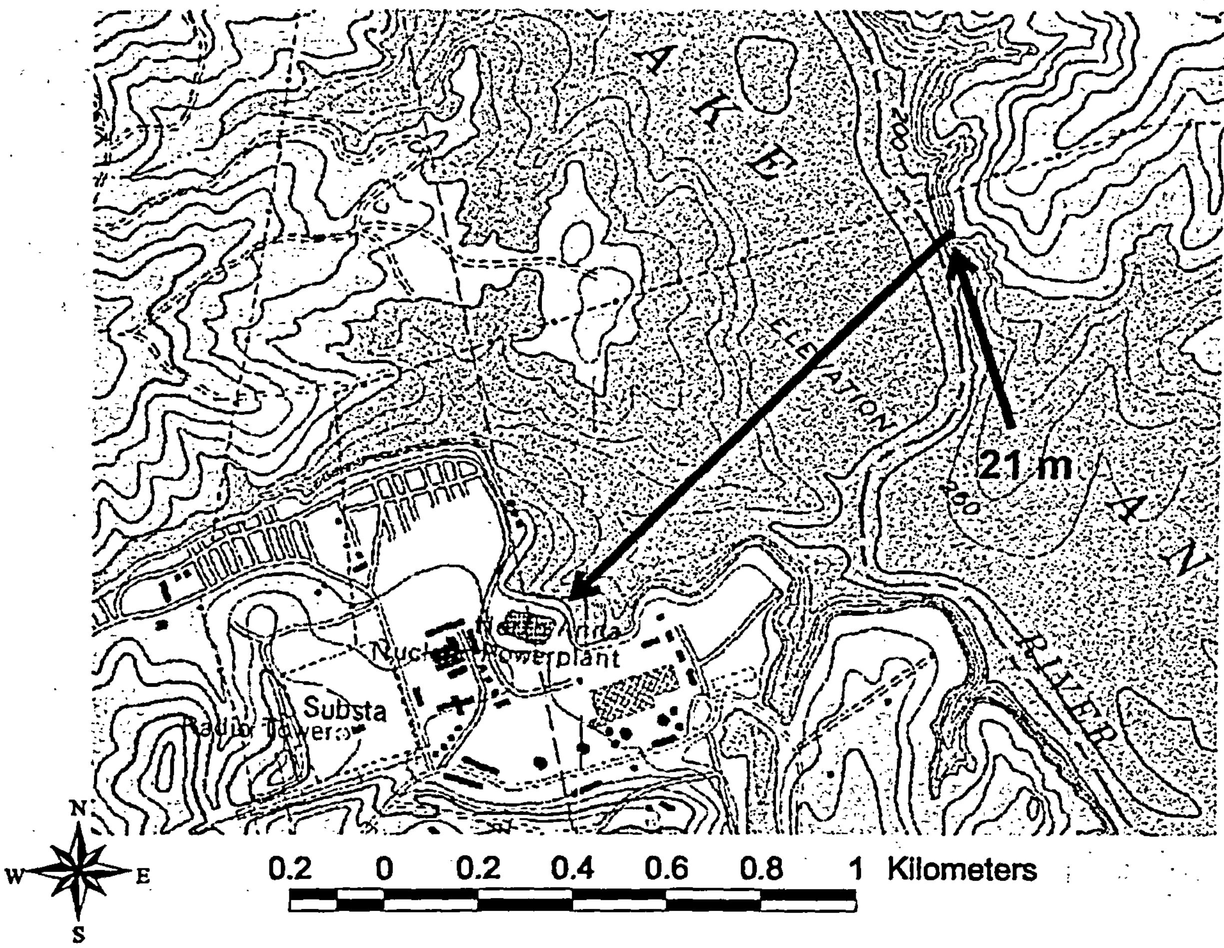


Figure 2.4.6-1 Landslide diagram resulting in wave traveling towards the ESP site. The 70 ft segment indicated in blue is the distance from the shore to the thalweg and represents that part of the water column displaced by the landslide.

The staff performed a numerical hydrodynamic modeling of Lake Anna using the three-dimensional transient-free surface model, Flow-3D. This model is a commercial software package that is supported though Flow Science, Inc. (Flow Science, Inc., "Flow-3D User's Manual," 2003). The model has a large user base and has been previously tested under a wide range of applications. Both the "Flow-3D User's Manual" and Hirt and Nichols, "Volume of Fluid (VOF) Method for the Dynamics of Free Boundaries," issued 1981, provide details of the model's theoretical background. A report by Bradford, "Numerical Simulation of Surf Zone

Dynamics," issued 2000, provides a recent and relevant application of the model for breaking waves, including free-surface breakup.

Flow-3D uses the finite volume method to solve the three-dimensional Reynolds-averaged Navier-Stokes equations. The physical domain simulated by the model can be divided into variable-sized hexahedral cells. This application used the Renormalized Group Model (Yakhot and Smith, "The Renormalization Group, the e-Expansion and Derivation of Turbulence Models," 1972) as the turbulence model. The staff divided the domain into uniform cells 1 ft in all directions. The staff simplified the model to two dimensions (the model domain was one cell wide), and the domain totaled approximately 500,000 computational cells. Bathymetry near the ESP site was approximated using a preimpoundment contour map, which was further simplified into two sloping regions (Figure 2.4.6-2). The first region extended approximately 3200 ft from the line following the lowest part of the lake bed (thalweg) towards the ESP site. Over this distance, the bottom rose 30 ft from an elevation of 200 to 230 ft MSL. The second region continued horizontally for approximately 900 ft, until intersecting the normal water surface level near the ESP site. Over this latter distance, the bottom rose 40 ft from an elevation of 230 to 270 ft MSL. The staff conservatively estimated bottom roughness to be equivalent to that of a smooth wall.

The staff initialized the numerical model with a 70-ft horizontal zone with a horizontal velocity of 55 ft/s, while the remainder of the lake was quiescent (see Figure 2.4.6-2). The staff assumed the boundary condition at midlake to be a wall that caused outgoing waves to reflect back towards the ESP site. The boundary condition on top of the domain was gauge (atmospheric) pressure.

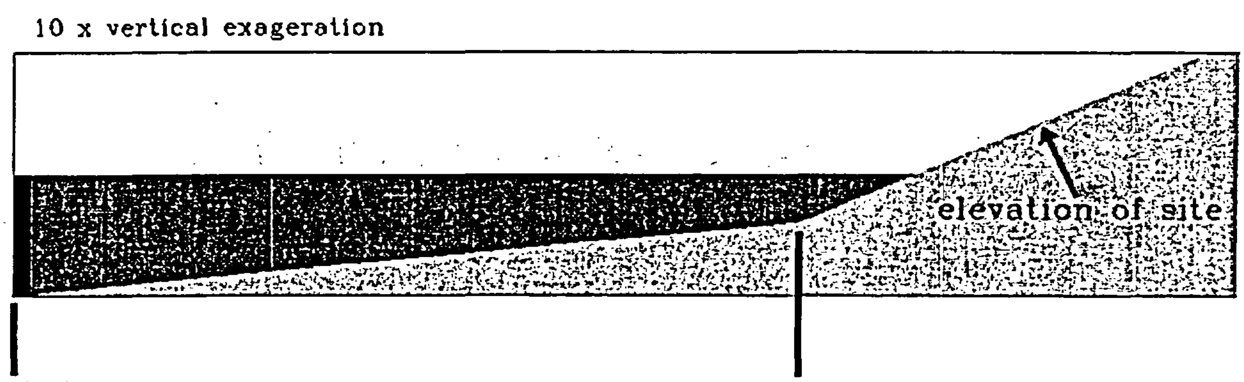


Figure 2.4.6-2 Initial conditions for the numerical model. The red zone at the left of the figure is the 70-ft-wide zone initialized at 55 ft/s.

The highest extent of the wave runup was reached after approximately 118 seconds and resembled a thin jet traveling up the smooth beach slope (see Figure 2.4.6-3). The highest extent of wave runup on the bank was just below an elevation of 270 ft MSL, and the water did not reach the elevation of the ESP site. At an elevation of 270 ft MSL, the wave was less than 1 ft thick. The wave reached 2 ft in thickness at an elevation of 260 ft MSL, which was 11 ft lower than the elevation of the ESP site.

10 x vertical exageration

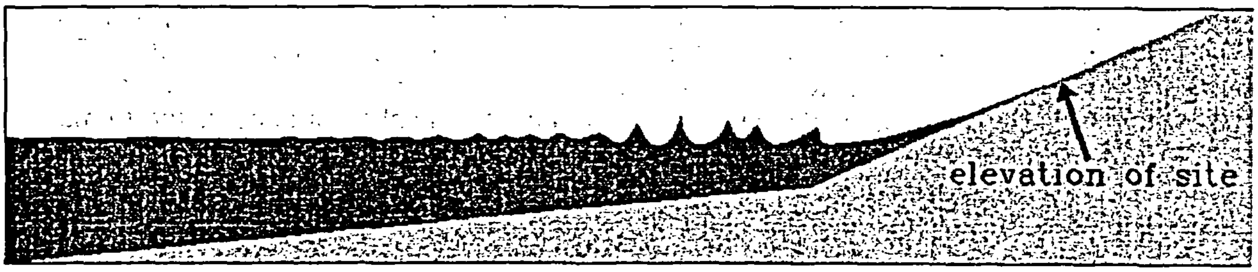


Figure 2.4.6-3 Highest extent of wave runup on shore

Therefore, the staff concluded that, even under conservative conditions of flooding generated by severe landslide, the ESP site would remain dry.

2.4.6.4 Conclusions

As set forth above, the applicant has provided information pertaining to probable maximum tsunami flooding showing that the elevation of such a flood is below the proposed grade of the ESP PPE (site footprint), and no flood protection measures are needed. Therefore, the staff concludes that the applicant has met the requirements relating to probable maximum tsunami flooding, with respect to 10 CFR 52.17(a), 10 CFR 100.20(c), and 10 CFR 100.23(c).

2.4.7 Ice Effects

The ESP site is located approximately 50 miles inland from the Chesapeake Bay (Potomac River) at an elevation of 271 ft MSL. The Chesapeake Bay climate influences the climate at the site throughout the year. The site is located on the shores of Lake Anna, a 17-mi-long reservoir that was formed when the North Anna Dam was constructed on the North Anna River. The site is located at the approximate longitudinal midpoint of the reservoir, 5 miles upstream of the North Anna Dam.

2.4.7.1 Technical Information in the Application

In SSAR Section 2.4.7.3, the applicant discussed historical ice formation in the region. The applicant reported that, after the construction of the dam and before the start of the operation of the existing NAPS units, an ice sheet formed on the lake. However, since the beginning of operation of those units, ice sheets have formed only on the upper reaches of Lake Anna. The staff requested, in RAI 2.4.7-1, that the applicant provide details, including location, duration, and height, of the occurrence of ice dams and subsequent downstream flood waves in the region. In its response, the applicant stated that no historical records indicate the formation of ice dams in the North Anna River, and therefore no records show any subsequent downstream flooding resulting from breaking of ice dams.

SSAR Section 2.4.7.4 states that, during the design of the intake structures, any COL applicant should assess the formation of anchor ice on the trash racks and screens. The staff requested, in RAI 2.4.7-2, that the applicant provide site characteristics relevant to such an assessment, including constraints on intake design based on a propensity for anchor ice and potential ice depth. In its response, the applicant stated that the site characteristics presented in SSAR Section 2.4.7.5 are not conducive to the formation of anchor ice on the trash racks and screens at the intake structure. The applicant indicated that no historical record shows the formation of ice crystals or granules in turbulent water (resembling slush, and referred to as frazil ice) in the existing intake structure. The applicant further stated that ice formation in the intake structure is an extremely rare event, such as when all units do not operate for prolonged periods during very severe wintry conditions. The applicant stated that, when any unit is in operation, heat loads dissipated in Lake Anna would preclude the formation of any frazil ice and thus the possibility of anchor ice. The applicant stated that an assessment would be made, at the COL stage, during the detailed design review regarding whether anchor ice could form on intake structures, and that the design would address any such icing issues identified.

SSAR Section 2.4.7.5 states that, during the period the existing units have operated at NAPS, surface ice has not formed in the area of the lake between the discharge and the intake of the plant. Ice sheets formed upstream of Route 208 during this period. The applicant stated that, because the area where ice sheets formed is located far from the main circulation path of cooling water, ice sheet formation will not affect operation of the intake for the ESP units. The applicant also stated that ice sheet formation is possible in the lake when all units may be offline during a sustained cold period. Based on daily mean air temperature data for 1961 to 1995, the applicant stated that, during several years, the mean daily air temperature was below freezing for 1 to 3 weeks in January and February. The applicant estimated the maximum ice thickness that could have formed under historically observed low air temperature conditions, assuming no units were in operation. The applicant estimated 200 degree-days below freezing during January and February 1977. The applicant used Assur's method (described by Chow, "Handbook of Applied Hydrology," 1964) to estimate an ice thickness of 13.5 in. The applicant concluded that this surface ice thickness would not impact water flow to intakes during restart of the units because of a water depth of at least 24 ft at the ESP intake.

SSAR Section 2.4.7.5 states that a separate UHS, if the selected plant design includes one, would supply the emergency cooling and service water needed to maintain the proposed units in a safe mode. The staff requested in RAI 2.4.7-3 that the applicant describe the source of cooling water needed for this purpose. In response to RAI 2.4.7-3, the applicant stated that initial filling and continued makeup water for UHS cooling tower basins would be obtained from Lake Anna.

The applicant stated that the UHS would provide both emergency and service water, and that ice-flow accumulation will not affect safety-related facilities. The staff requested, in RAI 2.4.7-4, that the applicant identify the constraints on the design of the UHS with regard to ice formation and that it indicate the maximum depth of ice formation in the water stored in the UHS to ensure the availability of sufficient water in the UHS during freezing. In its response, the applicant stated that the minimum water storage capacity of the UHS would be 4,090,625 ft^3. The UHS basins would be designed with sufficient depths to store the minimum water volume below the ice sheet, or measures would be taken to preclude the possibility of ice formation on the surface of the UHS basin.

SSAR Section 2.4.7.6 states that the PPE snow load is 50 lb/ft^2. The staff requested, in RAI 2.4.7-5, that the applicant confirm whether it calculated local snow load (a site characteristic) using the meteorological attributes discussed in SSAR Section 2.3.1.3.4. In its response, the applicant stated that the snow load for design of structures is determined using the equivalent depth of a 48-hour PMP on a 100-year return period snowpack. The 100-year snowpack is equivalent to 30.5 lb/ft^2, and the 48-hour PMP is equivalent to 107.9 lb/ft^2 or 20.75 in. of water.

2.4.7.2 Regulatory Evaluation

Section 1.8 of the SSAR presents a detailed discussion of the applicant's conformance to NRC regulations and regulatory guidance. The applicant identified the applicable regulations as 10 CFR 52.17(a), 10 CFR Part 100, 10 CFR 100.20(c), and 10 CFR 100.23(c) and the applicable regulatory guidance as RGs 1.27, 1.29, 1.59, 1.70, and 1.102, as well as RS-002. The staff reviewed this portion of the application for conformance with the applicable regulations, and considered the corresponding regulatory guidance, as identified above, with the exception of 10 CFR 100.23(c) which does not apply.

Section 2.4.7 of RS-002 provides review guidance used by the staff in evaluating this SSAR section. Acceptance criteria for this section are based on meeting the requirements of 10 CFR Parts 52 and 100, as they relate to identifying and evaluating hydrologic features of the site.

The regulations in 10 CFR 52.17(a) and 10 CFR 100.20(c) require that the site's physical characteristics (including seismology, meteorology, geology, and hydrology) be taken into account when determining its acceptability for a nuclear power reactor. To satisfy the hydrologic requirements of 10 CFR Parts 52 and 100, the SSAR should contain a description of any icing phenomena with the potential to result in adverse effects to the intake structure or other safety-related facilities for a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the proposed site. Ice-related characteristics historically associated with the site and region should be described, and an analysis should be performed to determine the potential for flooding, low water, or ice damage to safety-related SSCs. The analysis should be sufficient to evaluate the site's acceptability and to assess the potential for those characteristics to influence the design of SSCs important to safety for a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the proposed site. Meeting this guidance provides reasonable assurance that the effects of potentially severe icing conditions would pose no undue risk to the type of facility proposed for the site.

For those cases in which a reactor design is not specified, the ESP applicant may instead provide a PPE to characterize a facility or facilities for comparison with the hydrologic characteristics of the site. A PPE can be developed for a single type of facility or a group of candidate facilities by selecting limiting values of relevant parameters.

RG 1.59 provides guidance for developing the hydrometeorologic design basis.

To determine whether the applicant met the requirements of 10 CFR Parts 52 and 100, as they relate to ice effects, the staff used the following specific criteria:

- Publications of NOAA, USGS, USACE, and other sources are used to identify the history and potential for ice formation in the region. Historical maximum depths of icing should be noted, as well as mass and velocity of any large, floating ice bodies. The phrase, "historical low water ice affected," or similar phrases in streamflow records (USGS and State publications) will alert the reviewer to the potential for ice effects. The following items should be considered and evaluated, if found necessary:

- The regional ice and ice jam formation history should be described to enable an independent determination of the need for including ice effects in the design basis.

- If the potential for icing is severe, based on regional icing history, it should be shown that water supplies capable of meeting safety-related needs are available from under the ice formations postulated, and that safety-related equipment could be protected from icing as in the second item above. If this cannot be shown, it should be demonstrated that alternate sources of water are available that could be protected from freezing, and that the alternate source would be capable of meeting safety-related requirements in such situations.

- If floating ice is prevalent, based on regional icing history, potential impact forces on safety-related intakes should be considered. The structural design basis should include the dynamic loading caused by floating ice. (This item is to be addressed at the COL or CP stage.)

- If ice blockage of the river or estuary is possible, it should be demonstrated that the resulting water level in the vicinity of the site has been considered. If this water level would adversely affect the intake structure or other safety-related facilities of a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the proposed site, it should be demonstrated that an alternate safety-related water supply would not also be adversely affected.

- The applicant's estimates of potential ice flooding or low flows are acceptable if the estimates are no more than 5 percent less conservative than the staff estimates. If the applicant's estimates are more than 5 percent less conservative than the staff's, the applicant should fully document and justify its estimates or accept the staff estimates.

2.4.7.3 Technical Evaluation

In SSAR Section 2.4.7.3, the applicant discussed historical ice formation in the region. The applicant reported that, after the construction of the dam and before the start of the operation of the existing NAPS units, an ice sheet formed on the lake during the winter of 1977. Since NAPS began operating, ice sheets have formed only on the upper reaches of Lake Anna (upstream of the Route 208 bridge). The staff accessed the USACE historical database of ice jams on August 2, 2004. One ice jam was reported over the past 70 years for the North Anna River, on March 4, 1934, near the Doswell USGS gauge located approximately 16 miles downstream of the ESP site. This observation suggests that ice jam formation upstream of the ESP site is possible. The breakup of an upstream ice dam may result in flood waves at the ESP site. SSAR Section 2.4.7 does not provide regional characteristics of the location, duration, height of ice dams, and ice-induced high flows.

Because there is a historical record of ice jams on the North Anna River, the staff determined that the applicant should address the possibility of an ice jam or an ice dam formation upstream of the ESP site and should estimate the effect of a flood wave generated from the breakup of such an ice formation. This was Open Item 2.4-4. In response to Open Item 2.4-4 (Dominion, "Responses to Draft Safety Evaluation Report Open Items," March 3, 2005), the applicant evaluated the effect of a flood wave generated from the breakup of an ice jam or an ice dam formation upstream of the ESP site. Since the North Anna River is the largest tributary to Lake Anna, the applicant postulated the ice dam to occur on the North Anna River close to where it enters Lake Anna. The applicant selected this location to estimate the greatest volume of water that could be impounded by an ice dam, and the effect of the breaching of such a postulated ice dam on downstream flooding of the ESP site. Using topographic maps, the applicant estimated that the surface area of water impounded behind this ice dam would be 150 ac. The applicant estimated the volume of impounded water behind the ice dam as 1500 ac-ft by conservatively assuming a dam height of 10 ft and the depth of impoundment equal to 10 ft.

The applicant stated that the volume of impounded water behind the postulated ice dam (1500 ac-ft) on North Anna River is significantly smaller than the combined storage volume of Lakes Louisa and Orange (7671 ac-ft). As described in Section 2.4.4 of this SER, a simultaneous and complete failure of Lakes Louisa and Orange coincident with a PMF on Lake Anna's watershed is not sufficiently severe to flood the ESP site grade. Consequently, the applicant concluded that any flood produced by breakage of an ice dam on the North Anna River would also not result in flooding of the ESP site grade.

The staff reviewed the applicant's submission and determined that the applicant's approach (trying to bound a flood produced by breakage of an ice dam using the combined flood produced by simultaneous breakage of dams on Lakes Louisa and Orange) is satisfactory, based on the following rationale: The staff determined that, according to the USACE National Inventory of Dams, the height of the Lake Orange Dam is 44 ft and that of the Lake Louisa Dam is 25 ft. The staff also determined that no historical report exists of the formation of an ice dam on the North Anna River that exceeded 10 ft in height. Therefore, the staff concluded that no ice dam on North Anna River can create an impoundment of volume equal to the combined storage of Lakes Louisa and Orange. Consequently, any flood produced by breakage of an ice dam on the North Anna River will be smaller than the flood produced by simultaneous breakage of dams on Lakes Louisa and Orange. The staff determined in Section 2.4.4 of this SER that a flood produced by simultaneous breakage of dams on Lakes Louisa and Orange, coincident with the PMF in Lake Anna's watershed, would not flood the ESP site. Consequently, the staff concludes that any flood produced by breakage of the largest ice dams on North Anna River would also not flood the ESP site. Based on this review, the staff considers Open Item 2.4-4 to be resolved.

Based on the information provided in the SSAR regarding the applicant's UHS design proposed as part of the PPE, ice formation in the lake would not directly affect the UHS because its operation would be independent of the normal cooling water intake. However, ice formation in the lake could lead to increased reliance on the UHS. The staff's technical evaluation considered the safety implications of ice formation characteristics (i.e., sheet, anchor, and frazil ice) when all, some, or none of the four units (two existing and two future) would be in operation. The critical condition associated with freezing of the lake involves startup after all units have been shut down. For this condition, it is necessary to quantify ice characteristics to be used by the COL or CP applicant for design of the intake structures.

The staff independently verified the following hydrological characteristics provided by the applicant:

- The lowest monthly minimum air temperature at the Richmond Airport for any month was 15 °F in January 1977. The long-term average minimum air temperature for station VA7201 is 27.5 °F in January and 29.5 °F in February (NCDC, "Local Climatological Data Annual Summary and Comparative Data," temperature records through December 2001 for stations VA 7201, VA 6712, VA 6533, VA 5050, 2001).

- Three other NCDC weather stations surrounding the site recorded the following minimum temperatures. The lowest monthly minimum air temperature at Piedmont Research Station (station VA 6712, period of record August 1948 to December 2001) was 13 °F) in January 1977. The long-term average minimum air temperature is 24.0 °F in the month of January and 26.2 °F in February. The lowest monthly minimum air temperature at Partlow 3 WNW Station (station VA 6533, period of record June 1952 to December 1976) was 11 °F in January 1970. The long-term average minimum air temperature is 20.8 °F in the month of January and 23.8 °F in February. The lowest monthly minimum air temperature at Louisa Station (station VA 5050, period of record August 1948 to December 2001) was 15 °F in January 1977. The long-term average minimum air temperature is 24.8 °F in January and 26.8 °F in February.

The staff independently estimated the likely thickness of surface ice that may form near the intake structures. During this estimation, the staff used mean daily air temperatures recorded at the Piedmont Research Station (Station VA 6712 as discussed in the previous paragraph) located on the northwest ridge of the watershed draining into Lake Anna. The mean air temperatures at this station are available for water years 1949 to 2001. The staff estimated cumulative degree-days starting December 1 through March 31 for each water year. The most severe cumulative degree-days below freezing occurred in 1977 (Figure 2.4.7-1).

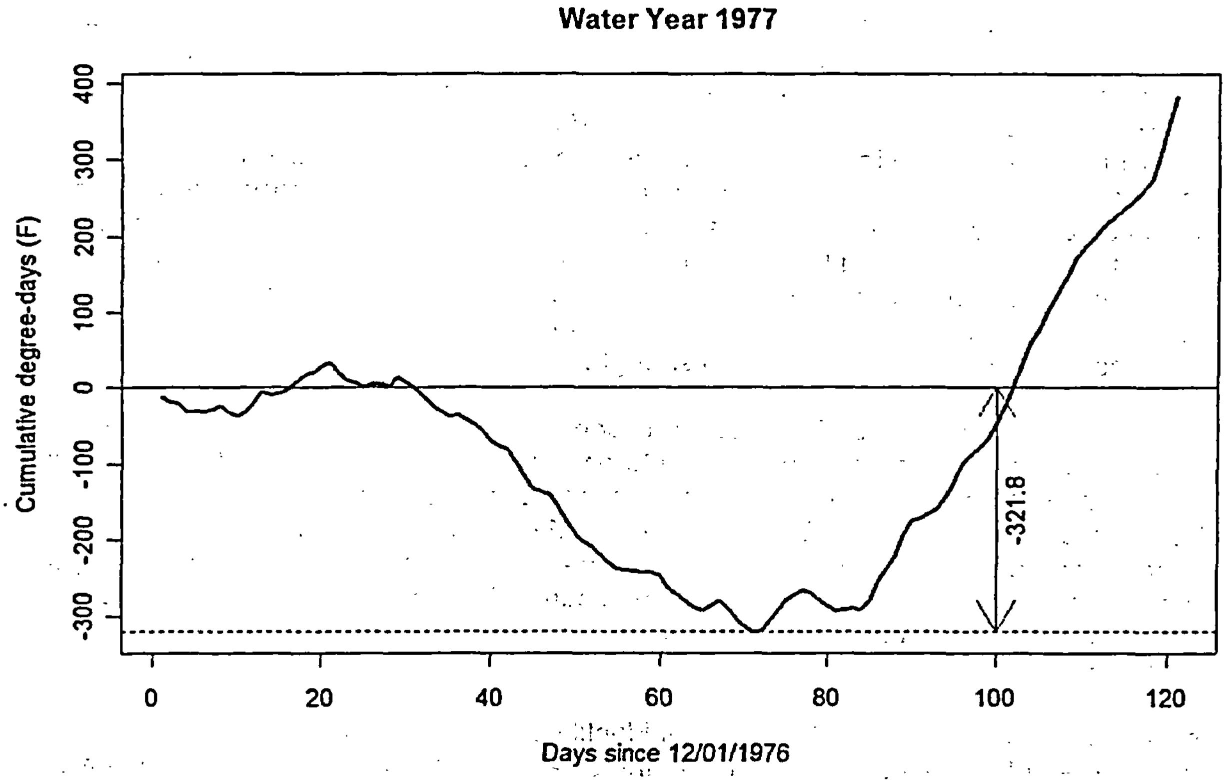


Figure 2.4.7-1 Accumulated degree-days since December 1, 1976, at the Piedmont Research Station meteorologic station

The maximum accumulated degree-days below freezing during the period of December 1, 1976, to March 31, 1977, was 321.8 °F, as shown in Figure 2.4.7-1. The staff used Assur's method to estimate a maximum ice thickness of 17.1 in. The staff's estimate is higher than the applicant's estimate of 13.5 in. However, this difference does not have any safety impact because, as explained below, the increase in ice thickness does not affect the intake for the proposed additional units. The ice sheet could be in place for several weeks. The staff determined, based on Figure 3.4-4 of the application and the minimum Lake Anna water level of 242 ft MSL, that the intake for the proposed additional units would be at least 20 ft below the minimum low-water level. The staff therefore concluded that the staff-calculated maximum estimated ice thickness of 17.1 in. would not hamper operation of the proposed additional units. However, the staff also determined that extended periods of water temperatures at freezing are possible near the intake structure. In Appendix A to this SER, the staff proposes the minimum lake water level of 242 ft MSL and the maximum ice thickness of 17.1 in. as site characteristics.

In response to RAI 2.4.7-2, the applicant stated that formation of frazil and anchor ice is an extremely rare condition that can only happen when all units are shut down and prolonged, wintry conditions prevail. The applicant stated that this issue would be addressed during design of the intake structures. However, the staff determined that minimum lake temperature is a site characteristic important as a design basis for a nuclear power plant or plants that might be constructed on the site. Therefore, this was Open Item 2.4-5.

In response to Open Item 2.4-5, the applicant stated in its submittal dated March 3, 2005, that the only scenario in which frazil and anchor ice could form is when all units have been shut down for a prolonged period in the winter, allowing the lake to cool to ambient temperature while conditions suitable for formation of frazil ice exist. The applicant stated that frazil ice can form in open water (i.e., no ice cover is present) with air and water temperatures near freezing, strong winds, and clear nights. The applicant stated that no safety-related facilities would be impacted if frazil ice were to form near the intake. The applicant also stated that the possibility of anchor ice accumulation on the trash racks and screens of the intake structure was remote and would be addressed during detailed engineering. In case the detailed engineering review concluded that anchor ice could form, the applicant proposed to use measures in the design of the intake structure to preclude formation of anchor ice. These measures may include heating the intake components subject to anchor ice formation, circulating warm water to the intake, and using coatings to reduce ice adhesion strength.

The staff determined that the ESP site supports conditions that may lead to formation of frazil and anchor ice near cooling water intake structures. The staff also determined that minimum lake temperature is not a suitable site characteristic to describe the potential for formation of frazil ice. According to the USACE Ice Engineering Manual, frazil ice forms in turbulent, supercooled water. Supercooled water is at a temperature below its equilibrium freezing point, which, for pure water, is 32 °F at atmospheric pressure. Supercooling can occur in lakes and rivers in turbulent, open-water areas when the air temperature is significantly less than 32 °F, usually 18 °F or lower.

In response to Open Item 2.4-5, the applicant identified the potential for frazil and anchor ice formation, in lieu of a minimum lake temperature, as a site characteristic for the cooling water intake structure. The potential for formation of frazil and anchor ice at the ESP site was included as a site characteristic in SSAR Table 1.9-1. The staff has determined that the applicant's proposed site characteristic reflects the conditions necessary for the formation of frazil ice, which are discussed above, and the staff considers Open Item 2.4-5 to be resolved.

SSAR Section 2.4.7.5 states that a separate UHS would supply the emergency cooling and service water needed to maintain the proposed units in a safe mode. The SSAR did not identify the source of the cooling water needed for this purpose. In response to RAI 2.4.7-5, the applicant stated that Lake Anna would be the source of initial filling and continued makeup water for the UHS basins. The staff finds this to be acceptable based on the large quantity of water available for makeup and the relatively small demand represented by the UHS.

SSAR Section 2.4.7.5 states that the UHS will provide both emergency and service water and that ice-flow accumulation will not affect safety-related facilities. The SSAR does not identify constraints on the design of the UHS with regard to ice formation, nor does it indicate the maximum depth of ice formation in the water stored in the UHS to ensure the availability of sufficient water in the UHS during freezing.

In response to RAI 2.4.7-4, the applicant stated that the minimum storage capacity of the UHS basins, if the selected plant design includes a UHS, would be maintained by either providing sufficient depth, such that the minimum water volume would be available below the ice sheet, or by adopting measures that would preclude the formation of an ice sheet on the surface of the UHS basins. In order to obviate the need for any limits on the operation of the proposed units, the UHS storage capacity should be large enough to accommodate ice formation. Through

DSER Permit Condition 2.4-7, the staff intended to ensure that the storage volume of the UHS basins would be sufficient to provide emergency cooling water to the respective ESP plants for 30 days, accounting for any and all losses from the UHS basins. This issue is addressed by **COL Action Item 2.4-7.** Pursuant to this item, given in Section 2.4.4.3 of this SER, a COL or CP applicant referencing the ESP will need to address whether 30-day cooling water supply will be available in the UHS storage basins to account for all potential losses. The issue raised by DSER Permit Condition 2.4-7 is thus resolved, and a permit condition is not necessary.

With respect to ice in a UHS, the staff requested that the applicant identify an additional UHS design-basis site characteristic. Section 2.3 of this SER discusses this issue in the resolution of Open Item 2.3-3. In its letter of March 3, 2005, responding to the staff's Open Items, the applicant agreed to use the staff's proposed characteristic of cumulative degree-days below freezing during winter estimated using measured air temperature at the Piedmont Research Station meteorologic station as the site characteristic appropriate for the estimation of thickness of an ice layer that may form in the UHS storage basins. Section 2.3.1.3 of this SER provides additional details on this issue.

SSAR Table 1.9-1 states that the PPE snow load is 30.5 lb/ft^2 based on the 100-year return period snowpack at the site. In response to RAI 2.4.7-3, the applicant stated that the 48-hour winter PMP is 20.75 in. and the weight of the 100-year return period snowpack is 30.5 lb/ft^2. In accordance with the criteria in RG 1.70, the snow load is obtained by using a 48-hour PMP event combined with a 100-year snowpack. The staff estimate of this combined load (using the applicant's 48-hour winter PMP value) is 138.4 lb/ft^2. The staff determined that this calculated site-specific snow load is overly conservative. Section 2.3.1 of this SER provides additional information regarding this issue.

Upon resolution of the open item related to snow load discussed in Section 2.3.1, the staff intended to establish the snow load for the site and to include the value determined in any ESP that the NRC might issue for the proposed ESP site. In response to Open Item 2.3-2, in its letter dated March 3, 2005, the applicant addressed the snow load issue. Section 2.3.1.3 of this report provides a detailed discussion on this issue and resolution to Open Item 2.3-2. Table 2.3.1-5 of this report provides the snow load to be considered for a future design. RG 1.70 specifies both the weight of the 100-year return period snowpack and the weight of the 48-hour PMWP to assess the potential snow loads on the roofs of safety-related structures. The staff's interim position on winter precipitation loads (see memorandum dated March 24, 1975, from H.R. Denton to R.R. Maccary) is summarized in the following paragraph as it applies to any future COL or CP applicant, and provides clarification as to the load combinations to be used in evaluating the roofs of safety-related structures.

As set forth in the staff's interim position on winter precipitation loads, the winter precipitation loads to be included in the combination of normal live loads for the design of a nuclear power plant or plants that might be constructed on a proposed ESP site should be based on the weight of the 100-year snowpack or snowfall, whichever is greater, recorded at ground level. Likewise, the winter precipitation loads to be included in the combination of extreme live loads to be considered in the design of a nuclear power plant or plants that might be constructed on a proposed ESP site should be based on the weight of the 100-year snowpack at ground level plus the weight of the 48-hour PMWP at ground level for the month corresponding to the selected snowpack. A COL or CP applicant may choose and justify its alternative method for defining the extreme load combination of maximum snow load and winter precipitation load by demonstrating that the 48-hour PMWP could neither fall nor remain on the top of the snowpack and/or building roofs because of the specific design of the roof. The future design of roofs for safety-related structures will be reviewed and approved based on NRC regulations and regulatory guidance.

2.4.7.4 Conclusions

As set forth above, the applicant has provided sufficient information pertaining to ice effects. Therefore, the staff concludes that the applicant has met the requirements concerning ice effects with respect to 10 CFR 52.17(a) and 10 CFR 100.20(c). Further, the applicant has considered the most severe natural phenomena that have been historically reported for the site and surrounding area with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, in establishing site characteristics pertaining to ice effects that are acceptable for design purposes.

2.4.8 Cooling Water Canals and Reservoirs

Lake Anna was constructed to provide a reliable supply of cooling water for NAPS. The North Anna Dam is located about 4 miles north of Bumpass, Virginia, and about 5 miles downriver from the ESP site. Lake Anna is about 17 miles long, with an irregular shoreline approximately 272 miles in length.

A series of dikes and canals separates Lake Anna into two segments. The larger segment, approximately 9600 ac, is named the North Anna Reservoir and serves as the storage impoundment. The smaller segment, approximately 3400 ac, is the WHTF and functions to dissipate the heat of the cooling water discharged from the existing units to the atmosphere.

The North Anna Dam is the only significant water control structure on the North Anna River. The dam is an earth-filled structure, approximately 5000 ft long with a 30-ft-wide crest at an elevation of 265 ft MSL. The dam has a 200-ft-long concrete spillway founded on bedrock. The spillway has three radial crest gates, each 40 ft wide and 35 ft high. Two skimmer gates, each 8.5 ft square, allow for the regulation of small discharges.

2.4.8.1 Technical Information in the Application

The applicant stated in SSAR Section 2.4.8 that the proposed Unit 3 would use a once-through cooling system for normal plant cooling. This cooling system would withdraw cooling water at a rate of 2540 cfs from a new intake structure located west of the intake structures for the existing Units 1 and 2. The cooling water would be pumped through the proposed Unit 3 condensers and auxiliary heat exchangers and then discharged into the WHTF for heat dissipation. A new outfall would be constructed adjacent to the existing units' outfall at the head of the discharge channel that leads into the WHTF.

The applicant informed the NRC of a revised approach to cooling the proposed Unit 4 in a letter dated March 31, 2004, and subsequently revised the SSAR to reflect this approach. The revised application states that the proposed Unit 4 would use a closed-cycle cooling system with dry cooling towers. This approach eliminates the use of Lake Anna as a source of makeup water for Unit 4, as well as the potential need for Unit 4 to rely on external water sources during drought conditions.

The applicant stated in SSAR Section 2.4.8 that the UHS for the proposed units would consist of a mechanical draft cooling tower over a buried water storage basin or other passive water storage facility, if the selected plant design includes a UHS. This facility would have its own water storage basins, independent of Lake Anna, for safety-related cooling and would contain water sufficient to maintain the plant in a safe shutdown mode for 30 days.

The applicant stated that a series of canals and dikes divides Lake Anna into two parts. The smaller part is the WHTF, and the larger part is the North Anna Reservoir. Circulating cooling water for the existing units is withdrawn from the North Anna Reservoir at the existing screen well, pumped through the condenser, and discharged through the circulating water discharge canal into the WHTF. The WHTF consists of three ponds that are interconnected by two canals. The discharge canal and the interconnecting canals are each designed to carry 8000 cfs. The applicant estimated a maximum discharge capacity of 6795 cfs when all four units are operating and concluded that the design water surface elevation of 251.5 ft MSL in the WHTF would not be affected because the canals were designed for a discharge of 8000 cfs. The canals are constructed through bedrock and are unpaved. Vegetation on all banks provides erosion protection, except near the discharge structure at Dike 3, where rip rap is provided.

The circulating water flows through these ponds and is discharged through six submerged skimmer gates located on Dike 3 into the North Anna Reservoir. The dikes are constructed of compacted earth material, except for a 700-ft section of Dike 3, which is constructed of dumped rock fill. The submerged skimmer gates are constructed within the rock fill section, and the rock fill section itself acts as an emergency overflow spillway. The crest of the rock fill section is at an elevation of 253.5 ft MSL, while the rest of the crest of the dike is at an elevation of 260 ft MSL. When water surface elevation in the WHTF exceeds 253.5 ft MSL, the rock fill section overtops, while ensuring the difference in water surface elevations between the WHTF and the North Anna Reservoir does not exceed 2 ft. The applicant estimated that the rock fill is likely to overtop once every 100 years.

2.4.8.2 Regulatory Evaluation

Section 1.8 of the SSAR presents a detailed discussion of the applicant's conformance to NRC regulations and regulatory guidance. The applicant identified the applicable regulations as 10 CFR 50.55a, "Codes and Standards"; GDC 2; GDC 44, "Cooling Water"; and 10 CFR Part 100 and the applicable regulatory guidance as RGs 1.27, 1.29, 1.59, 1.70, 1.102, and 1.125. The staff reviewed this portion of the application for conformance with the applicable regulations, and considered the corresponding regulatory guidance, as identified above, with the exception that an ESP applicant need not demonstrate compliance with the GDC or with 10 CFR 50.55a.

Acceptance criteria for this section are based on meeting the requirements of 10 CFR Parts 52 and 100, as they relate to identifying and evaluating the hydrologic features of the site.

The regulations in 10 CFR 52.17(a) and 10 CFR 100.20(c) require that the site's physical characteristics (including seismology, meteorology, geology, and hydrology) be taken into account when determining its acceptability for a nuclear power reactor. To satisfy the hydrologic requirements of 10 CFR Parts 52 and 100, the SSAR should contain a description of cooling water canals and reservoirs for a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the proposed site. The analysis related to cooling water canals and reservoirs should be sufficient to evaluate the site's acceptability and to assess the potential for those characteristics to influence the design of SSCs important to safety for a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the proposed site. Meeting this guidance provides reasonable assurance that the capacities of cooling water canals and reservoirs are adequate.

For those cases in which a reactor design is not specified, the ESP applicant may instead provide a PPE to characterize a facility or facilities for comparison with the hydrologic characteristics of the site. A PPE can be developed for a single type of facility or a group of candidate facilities by selecting limiting values of the relevant parameters.

2.4.8.3 Technical Evaluation

The staff visually inspected the site on February 23 and 24, 2004. The staff determined that the application accurately describes the cooling canals, outfalls, and levees near the ESP site.

Section 2.4.3 of this SER presents the staff's evaluation of the ability of Lake Anna (including the WHTF) to survive a PMF. The staff did not consider Lake Anna to be a safety-related reservoir since it is not a part of the proposed UHS for the proposed units.

The applicant stated that the UHS for the ESP units would consist of a mechanical draft cooling tower over a buried water storage basin, if the selected plant design includes a UHS. This UHS would have its own water storage basins that would be independent of the lake. In addition, the applicant stated that since the cooling tower basin for the UHS would contain its own 30-day water supply, water levels in Lake Anna would not affect the ability of the UHS to provide emergency cooling for safe shutdown.

The applicant suggested that the proposed Unit 3 would use a once-through cooling system during normal plant operation. The applicant also suggested that the proposed Unit 4 would use a closed-cycle cooling system with dry towers during normal plant operation. The limitation on the quantity of cooling water and other attributes of the cooling system design for the proposed Units 3 and 4 form part of the bases for site constraints. Consequently, the staff proposes the Unit 3 cooling water flow rate as a controlling PPE value, and the use of dry towers for Unit 4 as a permit condition in any ESP that the NRC might issue for the proposed ESP site. Appendix A to this SER contains a list of the permit conditions and controlling PPE values for this site.

The applicant did not provide details of the location and construction of the UHS buried water storage basin. Therefore, the staff could not review these details. The staff indicated that these details were needed because they relate to the reliability and stability of the UHS under the pressure head of ground water, which is at the grade level at certain locations of the ESP site. These data were the subject of RAIs 2.4.1-1 and 2.4.4-2. The need for location and construction details to determine differential head between ground water and the UHS was Open Item 2.4-6. Section 2.4.4.3 of this report addresses the feasibility of preventing UHS reservoir uplift because of buoyancy. Section 2.4.4.3 notes that the staff does not accept the applicant's conceptual approach (see March 3, 2005, letter from the applicant in response to open items) for preventing the UHS reservoir uplift; nonetheless, the staff accepts that a combination of water height limit in the reservoir and an engineered and monitored posttensioned anchorage system can reliably prevent any uplift of the UHS reservoir, should one be needed. A detailed engineering design of the UHS reservoir is not within the scope of the ESP review. Based on the above, the staff has determined that NRC regulations and regulatory guidance will ensure the safety of any future design and construction; therefore, information related to the location of the UHS reservoir is not needed for the ESP. Section 2.4.3.3 of this SER describes the maximum elevation of ground water at 270 ft MSL or 1 ft below the free surface, whichever is higher, as a site characteristic that would need to be considered by the COL or CP applicant in the detailed engineering design of the UHS to resist the potential for hydrostatic uplift, should the selected design include a UHS. Therefore, Open Item 2.4-6 is resolved.

Lake Anna and the WHTF are not safety-related facilities, as described in the application. Consequently, any future design at the ESP site that relies on the WHTF or on the North Anna Reservoir for any safety-related water use will be subject to further staff evaluation of such use. Through DSER Permit Condition 2.4-8, the staff intended to ensure that Lake Anna and the WHTF will not be used for safety-related water use. Instead, dedicated underground UHS water storage basins that are independent of Lake Anna and the WHTF will supply emergency cooling water supply for the ESP plants' UHS, if the selected plant designs includes a UHS. Further, the applicant has considered the design capacity of the cooling water canals and discharge structure in establishing that the addition of Units 3 and 4 would not affect the normal design-water level for WHTF. While the acceptability of the design of cooling water canals and discharge structure is beyond the scope of an ESP review, the staff determined that the NRC's existing regulatory process will ensure that any application proposing the use of Lake Anna for safety-related water will be appropriately evaluated, and therefore it is not necessary to impose DSER Permit Condition 2.4-8. The COL or CP applicant should address whether Lake Anna or the WHTF will be used for safety-related water withdrawals. This is **COL Action Item 2.4-8.**

The details provided in SSAR Section 2.4.8 associated with cooling water canals and reservoirs specific to the proposed Units 3 and 4 are identified by the applicant as PPE values in Table 1.3-1 of the application. The staff has determined that the once-through cooling water flow rate of 2540 cfs for Unit 3 is a controlling PPE value and the use of a dry cooling tower for Unit 4 is controlled by **Permit Condition 3.**

2.4.8.4 Conclusions

As set forth above, the applicant has provided sufficient information pertaining to cooling water canals and reservoirs. Therefore, the staff concludes that the applicant has met the requirements related to cooling water canals and reservoirs, with respect to 10 CFR 52.17(a) and 10 CFR 100.20(c).

2.4.9 Channel Diversions

The watershed upstream of the North Anna Dam lies in the Piedmont Physiographic Province, a rolling to hilly area, underlain mostly by metamorphosed sedimentary and crystalline rocks. These rocks are relatively resistant to erosion.

2.4.9.1 Technical Information in the Application

The applicant stated in SSAR Section 2.4.9 that there has been no major channel diversion of the North Anna River. The applicant also stated that localized ice jams would not create a low-flow period of sufficient duration to affect the cooling water supply.

The staff requested, in RAI 2.4.9-1, that the applicant document historical or geological evidence of possible diversions and meandering of the North Anna River upstream of the ESP site. In its response, the applicant stated that the possibility of upstream diversion of the North Anna River is extremely remote. The applicant used interpretations of USGS topographic maps and pre-dam aerial photographs to conclude that historical channel diversions have been minor and have occurred only in ancient geologic periods. These diversions are confined to valley bottoms of the existing drainage pattern.

The applicant also stated, in response to RAI 2.4.9-1, that the underground storage basins for the UHS, if the selected plant design includes a UHS, will be filled before plant startup and subsequently isolated from Lake Anna, thus eliminating Lake Anna as a backup water source for emergency cooling.

2.4.9.2 Regulatory Review

Section 1.8 of the SSAR presents a detailed discussion of the applicant's conformance to NRC regulations and regulatory guidance. The applicant identified the applicable regulations as Appendix A to 10 CFR Part 50, GDC 44, 10 CFR 52.17(a), 10 CFR Part 100, and 10 CFR 100.20(c) and applicable regulatory guidance as RGs 1.27 and 1.70, as well as RS-002. The staff reviewed this portion of the application for conformance with the applicable regulations, and considered the corresponding regulatory guidance, as identified above.

Section 2.4.9 of RS-002 provides the review guidance used by the staff in evaluating this SSAR section. Acceptance criteria for this section relate to 10 CFR Parts 52 and 100, insofar as they require that hydrological characteristics be considered in the evaluation of the site. The regulations at 10 CFR 52.17(a), 10 CFR 100.20(c), and 10 CFR 100.21(d) require that physical characteristics of the site (including seismology, meteorology, geology, and hydrology) be taken into account to determine the acceptability of a site for a nuclear reactor.

Channel diversion or realignment, which poses the potential for flooding or adversely affecting the supply of cooling water for a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the proposed site, is one physical characteristic that must be evaluated pursuant to 10 CFR 100.21(d). Consideration of criteria under 10 CFR 100.21(d) in view of this evaluation provides reasonable assurance that the effects of flooding caused by channel diversion resulting from severe natural phenomena would pose no undue risk to the type of facility proposed for the site.

For those cases in which a reactor design is not specified, the ESP applicant may instead provide a PPE to characterize a facility or facilities for comparison with the hydrologic characteristics of the site. A PPE can be developed for a single type of facility or a group of candidate facilities by selecting limiting values of the relevant parameters.

To meet the requirements of 10 CFR Parts 52 and 100, as they relate to channel diversion, the staff use the following specific criteria:

- A description of the applicability (potential adverse effects) of stream channel diversions is necessary.
- Historical diversions and realignments should be discussed.
- The topography and geology of the basin and its applicability to natural stream channel diversions should be addressed.
- If applicable, the safety consequences of diversion and the potential for high or low water levels, caused by upstream or downstream diversion, to adversely affect safety-related facilities, water supply, or the UHS should be addressed. RG 1.27 provides guidance on acceptable UHS criteria.

2.4.9.3 Technical Evaluation

The staff developed a basic understanding of the geomorphology of the region during its site visit. The staff's search did not produce any evidence of major channel diversion of the North Anna River. Channel diversions usually occur in relatively flat, deep alluvial plains where the river channel meanders greatly. The North Anna watershed upstream of the dam lies in the Piedmont Physiographic Province, a rolling to hilly area, underlain mostly by metamorphosed sedimentary and crystalline rocks. These rocks are relatively resistant to erosion. Because of these physiographic features, the staff concludes that channel diversion above Lake Anna is not likely.

Section 2.4.7 of this SER evaluates channel diversion caused by ice effects, and Section 2.4.11 of this SER evaluates the resulting low-water conditions.

In response to RAI 2.4.9-1, the applicant provided details of topographic and geomorphologic interpretations carried out using USGS topographic maps and pre-dam aerial photographs. The applicant concluded that diversion of North Anna River from its present drainage pattern is extremely remote. The staff concluded that the applicant has provided sufficient information to address this issue, and this information supports the above staff conclusion.

2.4.9.4 Conclusions

As set forth above, the applicant has provided information pertaining to channel diversions showing that channel diversion above Lake Anna is not likely. Therefore, the staff concludes that the applicant has met the requirements regarding channel diversions, with respect to 10 CFR Part 50, 10 CFR 52.17(a), 10 CFR 100.20(c), and 10 CFR 100.21(d). Further, the applicant has considered the most severe natural phenomena that have been historically reported for the site and surrounding area with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated in establishing that channel diversion is not likely at this site.

2.4.10 Flooding Protection Requirements

The proposed ESP site grade is at an elevation of 271 ft MSL.

2.4.10.1 Technical Information in the Application

In SSAR Sections 2.4.2 and 2.4.3, the applicant estimated the design-basis flood elevation at the ESP site to be 267.39 ft MSL. This elevation includes the effects of flooding caused by a PMF resulting from a PMP over the North Anna Dam's drainage area, wind setup, and wave runup. The applicant stated that all safety-related SSCs for the proposed additional units would be placed at or above the existing site grade of 271 ft MSL. The applicant therefore concluded that the ESP site does not require any safety-related flood-protection facilities.

In SSAR Sections 2.4.2 and 2.4.10, the applicant stated that the drainage design for the ESP site would consider the effects of intense local precipitation. Safety-related facilities associated with the ESP units would be designed to withstand the peak discharge resulting from local intense precipitation. In addition, the applicant stated that new facilities would incorporate measures to ensure that flooding as a result of either construction or operation of the proposed additional units would not compromise the existing units' safety-related facilities.

2.4.10.2 Regulatory Evaluation

Section 1.8 of the SSAR presents a detailed discussion of the applicant's conformance to NRC regulations and regulatory guidance. The applicant identified the applicable regulations as 10 CFR 50.55a, GDC 2, 10 CFR 52.17(a), and 10 CFR 100.20(c) and the applicable regulatory guidance as RGs 1.29, 1.59, 1.70, 1.102, and 1.125. The staff reviewed this portion of the application for conformance with the applicable regulations, and considered the corresponding regulatory guidance, as identified above, with the exception that an ESP applicant need not demonstrate compliance with the GDC or with 10 CFR 50.55a. Acceptance criteria for this section relate to 10 CFR Parts 52 and 100, insofar as they require that hydrological characteristics be considered in the evaluation of the site. Specifically, the regulations at 10 CFR 52.17(a) and 10 CFR 100.20(c) require that physical characteristics of the site (including seismology, meteorology, geology, and hydrology) be taken into account to determine the acceptability of a site for a nuclear reactor.

The regulation in 10 CFR 100.20(c) requires that the PMF be estimated using historical data. Meeting this requirement provides reasonable assurance that the effects of flooding or a loss of flooding protection resulting from severe natural phenomena would pose no undue risk to the type of facility proposed for the site.

For those cases in which a reactor design is not specified, the ESP applicant may instead provide a PPE to characterize a facility or facilities for comparison with the hydrologic characteristics of the site. A PPE can be developed for a single type of facility or a group of candidate facilities by selecting limiting values of the relevant parameters.

To determine whether the applicant met the requirements of 10 CFR Parts 52 and 100, as they relate to flooding protection, the staff used the following specific criteria:

- The applicability (potential adverse effects) of a loss of flooding protection should be described.
- Historical incidents of shore erosion and flooding damage should be discussed.
- The topography and geology of the basin and its applicability to damage as a result of flooding should be addressed.
- If applicable, the safety consequences of a loss of flooding protection and the potential to adversely affect safety-related facilities, water supply, or the UHS should be addressed. RG 1.27 provides guidance on acceptable UHS criteria.

2.4.10.3 Technical Evaluation

During its review of SSAR Sections 2.4.2 and 2.4.3, the staff estimated the design-basis flood elevation to be 270 ft MSL. The staff estimated local, intense precipitation for the ESP site to be 18.3 in./hr. Table 2.4.2-1 in Section 2.4.2 of this SER provides the complete hyetograph (a chart or graphic representation of the average distribution of rain over the site surface area) for the 6-hour local, intense precipitation.

Since the ESP site grade (at an elevation of 271 ft above MSL) is higher than the design-basis flood elevation (270 ft MSL), flood protection requirements do not apply. In the DSER, however, the staff indicated that safety-related SSCs that may be constructed on the proposed site should be constructed with ingress and egress openings located above the elevation of 271 ft MSL to ensure they are protected from flooding. The staff intended to ensure protection of safety-related SSCs from flooding by specifying minimum ingress and egress elevation in DSER Permit Condition 2.4-9 and to include the grade elevation as a site characteristic in any ESP that might be issued for the proposed site. However, the staff determined that DSER Permit Condition 2.4-9 is unnecessary since any ESP that might be issued will include a site characteristic specifying the maximum water surface elevation and any application referencing such an ESP should demonstrate that the proposed design bounds this site characteristic. This will ensure that all SSCs will be protected from flooding. Accordingly, **COL Action Item 2.4-4** and **COL Action Item 2.4-5**, as described in Section 2.4.2.3 of this SER, provide for the review of specific design and engineering details of SSCs for flooding protection according to NRC regulations and regulatory guidance at the COL or CP stage.

The need to protect the slope embankment at the intake location is based on the potential for degradation resulting from water and wave action. Through DSER Permit Condition 2.4-10, the staff intended to provide erosion protection to protect the slope embankment. However, the staff determined that it is sufficient for any COL or CP applicant to address the issue of slope embankment protection during design of the intake structure. This is **COL Action Item 2.4-9.** In its review of a COL or CP application that references any ESP that might be issued, the staff will evaluate the design of the intake structure in accordance with NRC regulations and regulatory guidance.

Any COL or CP applicant will ensure that the flood control measures protecting the safety-related facilities of the existing units will not be compromised during construction or operation of the proposed units. The staff intended to ensure flood protection of the existing units' SSCs during construction and operation of the ESP unit by imposing DSER Permit Condition 2.4-11. However, the staff determined that 10 CFR 50.59 requires the licensee of the existing units to evaluate changes to flood protection provisions, which are described in the existing units' final safety analysis reports. Since the current licensee controls access to the exclusion area, as described in Section 2.1.2 of this SER, the holder of any ESP issued for the North Anna site, and any COL or CP applicant referencing such an ESP will be able to construct and operate a new unit only in accordance with the terms of an agreement with the licensee of the existing units. The licensee of the existing units is obligated to satisfy the provisions of 10 CFR 10.59, and it will ensure that such an agreement reflects the results of the evaluations performed pursuant to 10 CFR 50.59. Accordingly, the requirements of Part 50 will ensure that any changes to the existing units' flood protection measures resulting from construction on the ESP site will be adequately controlled. Therefore, DSER Permit Condition 2.4-11 is unnecessary.

2.4.10.4 Conclusions

As set forth above, the applicant has provided information pertaining to flooding protection requirements showing that the design-basis flood elevation is below the proposed grade of the ESP PPE (site footprint), and no flood protection measures are needed. Therefore, the staff concludes that the applicant has met the flood protection requirements with respect to 10 CFR 52.17(a) and 10 CFR 100.20(c). Further, in making this demonstration, the applicant has considered the most severe natural phenomena that have been historically reported for the site and surrounding with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.11 Low-Water Considerations

The site is adjacent to Lake Anna, which provides the cooling water for the current and proposed units. Events that may potentially reduce or limit the availability of cooling water at this site include low lake level, seiches, wind-induced set down, and intake blockages from sediment or from ice.

The normal cooling water supply for non-safety-related needs of the proposed units would be obtained from Lake Anna, created by the North Anna Dam. The UHS underground storage basins, if the selected plant design includes a UHS, would provide a 30-day supply of emergency cooling water. The applicant stated that the UHS storage basins would be maintained full and are not dependent upon the water level in Lake Anna for their safety function.

The applicant stated in SSAR Section 2.4.11.1 that for the new units, the anticipated minimum lake level for operation would be the same as the existing units, at elevation 242.0 ft MSL. A lake water level below 242.0 ft MSL could warrant a shutdown of the new and exiting units, however, it would not impact safety-related systems since the water supply from the lake is used only for normal cooling of non-safety-related systems.

Normal operation for the proposed Unit 3 would use a once-through cooling system, operated with water drawn from Lake Anna. The applicant's March 31, 2004, letter to the NRC states that the normal operation cooling system for proposed Unit 4 would use dry cooling towers. Underground water storage basins would supply the proposed UHS for both proposed units, if the selected plant design includes a UHS. The applicant subsequently revised the SSAR to be consistent with the statements made in this letter.

2.4.11.1 Technical Information in the Application

To determine the impact of new units on Lake Anna water levels, the applicant considered, in SSAR Section 2.4.11, constraints on water availability resulting from low flow in streams, seiches, drought, and from future controls. In SSAR Section 2.4.11.4, the applicant cited its water budget calculation that estimates the lake elevation changes associated with the addition and operation of the proposed Unit 3, which are included in the environmental report, Section 5.2.2. This water budget analysis considers the impact of induced evaporation associated with the proposed Unit 3 cooling system, and it provides information on the frequency and magnitude of low-water conditions in the lake.

In RAI 2.4.11-1, the staff requested information regarding critical ambient conditions, such as air temperature and relative humidity, which might limit operation of a UHS if included in the design. The staff also requested information regarding the meteorological conditions that might constrain the safety-related cooling tower design of the new units. In its response, the applicant referred to its response to the same question in RAI 2.3.1-1. In its response to RAI 2.3.1-1, the applicant identified the controlling parameters as the wet-bulb temperature and coincident dry-bulb temperature for the type of UHS being considered for Unit 3, which could be a mechanical draft cooling tower over a buried water storage basin or other passive water storage facility, depending on the design selected at the COL or CP stage. The applicant also stated that the meteorological conditions that would result in the maximum evaporation and drift loss of water from an engineered UHS and the corresponding minimum cooling from such a UHS are the critical wet and dry-bulb conditions for the UHS cooling tower design.

In Section 2.4.11.3 of the SSAR, the applicant stated that the minimum observed Lake Anna water surface elevation was 245.1 ft MSL on October 10, 2002. This low-water level followed the driest September to August period and the third driest October to September period in the 108-year record for Virginia's statewide precipitation.

In SSAR Section 2.4.11.4, the applicant provided the results of a water budget analysis to estimate the lake levels, which is described in further detail in Section 5.2.2 of Part 3 of the applicant's environmental report. With all four units operating, the applicant estimated the minimum lake level to be 242.6 ft MSL. In SSAR Section 2.4.11.1, the applicant stated that the shutdown threshold level for the existing units is an elevation of 244.0 ft MSL. The shutdown threshold level for the new units would be an elevation of 242.0 ft MSL. Section 2.4.11.3 of this SER further discusses these two different shutdown threshold levels and the related minimum lake elevations.

In RAI 2.4.11-2, the staff requested the applicant to describe likely upstream land-use changes and changes in downstream water demand that could alter the frequency of low-flow conditions and related minimum water elevation in Lake Anna. This RAI also asked the applicant to calculate the availability of cooling water during critical low-flow periods, including sufficient margins to account for future urbanization of the watershed. In addressing this issue, the applicant stated that its response to the staff's environmental RAI E4.2.2-2 describes the projected upstream development based on growth plans for the counties in the drainage area. All three upstream counties (Louisa, Orange, and Spotsylvania) anticipate future growth in areas near existing towns. Increased development would impact low-flow conditions because of increased ground water withdrawals and increased impervious areas. Decreased ground water levels may lead to reduced baseflow to Lake Anna. The applicant stated that the anticipated development is small compared to the size of the watershed and concluded that its impact on low-flow conditions will be small. The applicant also concluded that the water balance model presented in Section 5.2.2 of Part 3 of the environmental report would be accurate, even after consideration of the impact resulting from upstream land-use changes. The applicant described the margins available in the cooling water supply in its response to RAI 2.4.1-1.

2.4.11.2 Regulatory Evaluation

Section 1.8 of the SSAR presents a detailed discussion of the applicant's conformance to NRC regulations and regulatory guidance. The applicant identified the applicable regulations as GDC 2 and 44, as well as 10 CFR 100.23(c), and identified the applicable regulatory guidance as RGs 1.27 and 1.70, as well as RS-002. The staff reviewed this portion of the application for conformance with the applicable regulations, and considered the corresponding regulatory guidance, as identified above.

Acceptance criteria for this section relate to the following regulations and criteria:

- 10 CFR Parts 52 and 100 require that hydrologic characteristics be considered in the evaluation of the site.
- 10 CFR 100.23 requires, in part, that siting factors to be evaluated must include cooling water supply.

The regulations in 10 CFR Parts 52 and 100 require, in part, that hydrologic characteristics be considered in the evaluation of a nuclear power plant site. In order to satisfy 10 CFR Parts 52 and 100, the applicant should describe in the SSAR the surface and subsurface hydrological characteristics of the site and region. In particular, the UHS for the cooling water system may consist of water sources affected by, among other things, site hydrological characteristics that may reduce or limit the available supply of cooling water for safety-related SSCs. Site hydrological characteristics that may reduce or limit the flow of cooling water include those resulting from river blockage or diversion, tsunami runup and drawdown, and dam failure.

Meeting the requirements of 10 CFR Parts 52 and 100 provides assurance that severe hydrologic phenomena, including low-water conditions, would pose no undue risk to the type of facility proposed for the site.

For those cases in which a reactor design is not specified, the ESP applicant may instead provide a PPE to characterize a facility or facilities for comparison with the hydrologic characteristics of the site. A PPE can be developed for a single type of facility or a group of candidate facilities by selecting limiting values of the relevant parameters.

The regulation in 10 CFR 100.23 requires the evaluation of siting factors, including cooling water supply. The evaluation of the emergency cooling water supply for a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the proposed site should consider river blockages, diversion, or other failures that may block the flow of cooling water, tsunami runup and drawdown, and dam failures.

The regulation at 10 CFR 100.23 applies to this section because the UHS for the cooling water system consists of water sources that are subject to natural events that may reduce or limit the available supply of cooling water (i.e., the heat sink). Natural events, such as river blockages or diversion or other failures that may block the flow of cooling water, tsunami runup and drawdown, and dam failures, should be conservatively estimated to assess the potential for these characteristics to influence the design of SSCs important to safety for a nuclear power plant or plants of a type specified by the applicant (or falling within a PPE) that might be constructed on the proposed site. The available water supply should be sufficient to meet the needs of the plant or plants to be located at the site; those needs may fall within a PPE (e.g., the stored water volume of the cooling water ponds), if an applicant uses that approach. Specifically, those needs include the maximum design essential cooling water flow, as well as the maximum design flow for normal plant needs at power and at shutdown.

To meet the requirements of the hydrologic aspects of the above regulations, the specific criteria discussed in the paragraphs below are used. Acceptance is based principally on the adequacy of the UHS to supply cooling water for normal operation, anticipated operational occurrences, safe shutdown, cooldown (first 30 days), and long-term cooling (periods in excess of 30 days) during adverse natural conditions.

Low Flow in Rivers and Streams

For essential water supplies, the low-flow/low-level design for the primary water supply source is based on the probable minimum low flow and level resulting from the most severe drought that can reasonably be considered for the region. The low flow and level site parameters for operation should be such that shutdowns caused by inadequate water supply will not trigger frequent use of emergency systems.

Low Water Resulting from Surges, Seiches, or Tsunami

For coastal sites, the appropriate PMH wind fields should be postulated at the ESP stage to provide maximum winds blowing offshore, thus creating a probable minimum surge level. Low-water levels on inland ponds, lakes, and rivers caused by surges should be estimated from probable maximum winds oriented away from the plant site. The same general analysis methods discussed in Sections 2.4.3, 2.4.5, and 2.4.6 of RS-002 are applicable to low-water estimates resulting from the various phenomena discussed. If the site is susceptible to such phenomena, minimum water levels resulting from setdown (sometimes called runout or rundown) from hurricane surges, seiches, and tsunami should be verified at the COL or CP stage to be higher than the intake design basis for essential water supplies.

Historical Low Water

If historical flows and levels are used to estimate design values by inference from frequency distribution plots, the data used should be presented so that an independent determination can be made. The data and methods of NOAA, USGS, SCS, USBR, and USACE are acceptable.

Future Controls

This section is acceptable if water use and discharge limitations (both physical and legal), already in effect or under discussion by responsible Federal, regional, State, or local authorities, that may affect water supply for a nuclear power plant or plants of a type specified by the applicant that might be constructed on the proposed site have been considered and are substantiated by reference to reports of the appropriate agencies. The design basis should identify and take into account the most adverse possible effects of these controls to ensure that essential water supplies are not likely to be negatively affected in the future.

2.4.11.3 Technical Evaluation

The applicant has stated that the proposed additional units will not rely on Lake Anna for safety-related water needs. Further, the applicant has proposed engineered subsurface water reservoirs and mechanical cooling towers to fulfill UHS requirements, should the selected plant design need a conventional UHS.

The staff has performed its review in accordance with the guidance in RS-002 regarding the frequency of shutdown of operating units. Low upstream tributary inflow and minimum lake elevations for the operation of all four units should be such that shutdowns caused by inadequate water supply do not cause frequent use of emergency systems. Hydrologic conditions that could lead to low lake elevations can be characterized as follows:

- gradual, such as a sustained drought
- abrupt and prolonged, such as failure of the North Anna Dam
- abrupt but temporary, such as hillslope failure

The technical evaluation in this section focuses on the gradual decrease in water elevation associated with drought; Section 2.4.4 of this SER discusses abrupt and prolonged low-flow conditions resulting from a failure of the North Anna dam. Section 2.4.6 addresses the abrupt but temporary low-flow condition caused by a hillslope failure. Wave runup results in high water level from a baseline pool level as the wave approaches the shore and a low water level as the wave recedes from the shore. Declines in the lake elevation will be sufficiently gradual to provide advance warning to properly respond to low-water conditions during which the UHS would be used, except in the case of failure of the North Anna Dam.

The staff performed an independent analysis of the Lake Anna water budget under critical conditions to estimate the extreme low-water elevation. The staff constructed a coupled water budget and temperature model consistent with the limited available data. The water-budget component of the model was based on a lumped representation of the conservation of mass. The water temperature component of the model was a lumped, two-compartment representation of the lake based on the conservation of energy. The water budget and temperature components are linked through the evaporation process.

In this water-budget model, changes in lake storage over time were equal to the differences between the inflows and the outflows. Inflows consist of runoff from drainage upstream of the lake and precipitation occurring directly on the lake. Outflows consist of the natural and induced evaporations and releases from the dam.

The staff estimated inflows from the drainage upstream of the lake using data from an adjacent drainage basin, the Little River drainage basin, adjusted for the difference in drainage areas. The Little River drainage area comprises 107 mi^2 adjacent to the North Anna drainage basin. Based on a review of streamflow records from USGS gauge 01671100 (Little River near Doswell, Virginia), the staff selected the period from October 2001 to September 2002 as the critical water year. The staff used precipitation records from the meteorological station at the Richmond, Virginia, airport to estimate direct precipitation on the lake.

The staff estimated outflows from the lake based on the current operating rules for the Lake Anna Dam. The staff's analysis assumed that the current units and the additional unit 3 continue to operate until the lake water level falls below 242 ft MSL.

The staff estimated the evaporative loss from the ambient compartment of the lake from the Massachusetts Institute of Technology model (Ho, E. and E.E. Adams, "Final Calibration of the Cooling Lake Model for North Anna Power Station," Ralph M. Parsons Laboratory, Aquatic Science and Environmental Engineering, Department of Civil Engineering, Massachusetts Institute of Technology, Report No. 295, August, 1984). This model was empirically validated through onsite observation for the licensing of NAPS Units 1 and 2 and is acceptable. The staff derived the evaporative loss from the fixed temperature compartment using the applicant's PPE values. The staff performed sensitivity analyses to assess the impact of various evaporative loss assumptions.

The staff determined the minimum water surface elevation to be 242.6 ft MSL when the existing units and the proposed Unit 3 are operating. The staff estimated that water surface elevation in the lake would fall to this minimum elevation only infrequently during low-water years. The applicant has proposed a minimum water surface elevation of 242 ft MSL in SSAR Section 2.4.11.1.

Since the applicant's proposed minimum water surface elevation site characteristic is lower than the staff's estimate, the applicant's value is acceptable.

In RAI 2.4.11-1, the staff requested that the applicant estimate the frequency of low-water conditions that could result in use of the UHS. The staff further asked the applicant to describe in greater detail the critical ambient conditions, such as combinations of temperature and relative humidity, that might limit operations under low-water conditions. In its response, the applicant only discussed the issue related to evaporation loss from the UHS. The applicant identified the meteorological conditions resulting in the maximum evaporation and drift loss of water from the engineered UHS as the worst 30-day average combination of controlling atmospheric parameters. The staff's assessment of meteorological site characteristics is included in Section 2.3 of this SER.

The staff notes that, in addition to evaporation losses, icing in a UHS storage basin, if included in the selected plant design, may also result in limits on UHS operation to ensure the availability of sufficient water during freezing to supply both emergency and service water. The staff determined, in Section 2.3.1.3 of this SER, that the 7-day average of low air temperature is 19.9 °F. In order to obviate the need for limits on the operation of the proposed units, any COL or CP applicant should design the UHS storage capacity to accommodate ice formation at the sustained low-air temperature of 19.9 °F. As discussed in Section 2.4.7 of this SER in response to the issue raised by DSER Permit Condition 2.4-7, the staff included **COL Action Item 2.4-7**, in which a COL or CP applicant referencing this ESP should address whether a 30-day cooling water supply will be available in the UHS storage basins to account for all potential losses, including ice formation. The applicant's response to RAI 2.4.11-1 is satisfactory, based on the discussion above.

Future land-use development, such as urbanization of the upstream Lake Anna watershed, may lead to changes in consumptive water use. As an indicator of future development, the population of Louisa County, where the site is located, grew 25 percent from 1979 to 2000, and residential land use grew from 1.8 to 5.5 percent during the same period. Likely upstream land-use changes and changes in downstream water demand could alter the occurrence of low-flow conditions and related minimum lake levels.

In RAI 2.4.11-2, the staff asked the applicant to describe likely upstream land use changes and changes in downstream water demands that would likely alter the intensity or frequency of low-flow conditions and to calculate the availability of cooling water during critical low-flow periods. In its response to RAI 2.4.11-2, the applicant indicated that upstream development is expected to be small compared to the size of the watershed and will have only a small effect on low-flow conditions. The applicant noted that its response to a similar question in RAI E4.2.2-2 provides a description of the projected upstream development based on available county growth management plans. In its response to RAI 2.4.11-2, the applicant stated that the availability of cooling water during low-flow conditions has been considered in the water balance model presented in Section 5.2.2 of the application and summarized in SSAR Section 2.4.11. The staff reviewed the applicant's response and determined that the applicant has adequately discussed the effects of upstream land-use change in the drainage area. The applicant identified cooling water needs that may lead to restrictions on the operation of future plants because of changes in the frequency of low-flow conditions and related minimum water elevation in Lake Anna. Any COL or CP applicant should identify the most restrictive cooling water needs to account for the frequency of low flow conditions and related minimum water elevation in Lake Anna and propose corresponding actions to account for such conditions. This is **COL Action Item 2.4-10**, previously identified as DSER COL Action Item 2.4-1. The applicant's response to RAI 2.4.11-2 is satisfactory, based on the discussion above.

2.4.11.4 Conclusions

As set forth above, the applicant has provided information pertaining to low-water considerations, including hydrologic conditions that could lead to low lake elevations, conditions that could result in use of a UHS, and potential effects of upstream land-use change in the drainage area. Therefore, the staff concludes that the applicant has met the requirements related to low-water considerations with respect to 10 CFR 52.17(a) and 10 CFR 100.20(c). Further, the applicant has considered the most severe natural phenomena that have been historically reported for the site and surrounding area with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated in establishing low-water conditions for use in design.

2.4.12 Ground Water

NAPS is located in the Piedmont Physiographic Province in an area underlain by crystalline bedrock. The powerblock for the proposed additional units would be sited on soil that was disturbed during construction of the now-abandoned NAPS Units 3 and 4. Further disturbance of the subsurface environment is expected during construction of the proposed additional units.

2.4.12.1 Technical Information in the Application

In SSAR Section 2.4.12, the applicant provided a description of regional hydrogeology and ground water conditions based on reports prepared by USGS, EPA, and the Commonwealth of Virginia. In a generalization to the Piedmont Physiographic Province, Trapp and Horn ("Ground Water Atlas of the United States, Segment 11, Delaware, Maryland, New Jersey, North Carolina, Pennsylvania, Virginia, West Virginia," USGS, Hydrologic Investigations Atlas 730-L, 1997) characterize the bedrock as "almost impermeable" and as yielding "water primarily from secondary porosity and permeability provided by fractures." Water occurs primarily in a regolith (a layer of weathered, heterogeneous material overlying bedrock) of variable thickness. In discussing the hydrogeology of areas underlain by crystalline bedrock, Trapp and Horn state that the porosity of the regolith ranges between 20 and 30 percent, while the porosity of the bedrock is about 0.01 to 2 percent. Most fractures in the bedrock are steeply inclined, while "the size, number, and interconnection of the fractures decreases with depth." Recharge to the aquifers in the Piedmont Physiographic Province occurs primarily from infiltration. Within the subsurface, water tends to follow the topography, moving from upland recharge areas to discharge areas at lower elevations.

The applicant based most of its description of local hydrogeology at the North Anna site on previous site investigations. In addition, the applicant conducted more recent site sampling and analysis as part of its subsurface investigation program. The applicant drilled seven boreholes (B01 to B07) and installed nine observation wells (OW-41 to OW-49) as part of this program. The applicant stated that the subsurface consists of five zones—the crystalline parent rock, weathered rock, two zones of saprolite (altered and weathered bedrock caused by continual exposure to moisture still in place) distinguished by the amount of core stone in each zone, and residual soils. The borehole logs identify a sixth material, the fill, which occurs in the area near the abandoned Units 3 and 4. The applicant screened eight of the observation wells in the unconsolidated materials (residual soil, saprolite, or weathered rock) and one in the parent rock.

Previous studies (e.g., Revision 38 of the NAPS UFSAR) predicted that maximum ground water elevations beneath the site in the existing plant area could reach 265 to 270 ft MSL based on a uniformly sloping water table from 271 ft MSL at the toe of the slope south of abandoned Units 3 and 4 to the 250 ft MSL elevation of Lake Anna. Figure 2.4-16 in the SSAR shows that water levels in new wells, OW-844 and OW-841, vary from about 267 ft MSL (at OW-844) to 250 ft MSL (at OW-841). The applicant used these measurements to support a design ground water level of 265 to 270 ft MSL in the PPE (site footprint) of the ESP site.

The applicant conducted slug tests in the newly installed wells to provide estimates of saturated hydraulic conductivities. Saturated hydraulic conductivities for the wells drilled into the unconsolidated subsurface zone range from 0.2 to 3.4 ft/d. The slug test failed conditions set by the Bouwer-Rice method ("A Slug Test Method for Determining Hydraulic Conductivity of

Unconfined Aquifers with Completely or Partially Penetrating Wells, Water Resources Research, Vol. 12, No. 3, pp. 423–428, 1976) for the well screen into the consolidated rock because of the short duration of stable data. This is frequently the case in consolidated rock. The applicant estimated the hydraulic conductivity using available slug test data and presented the results in SSAR Table 2.4-16. The saturated hydraulic conductivity values reported for this well are 1.8 to 3.1 ft/d.

SSAR Figure 2.4-15 depicts ground water levels between December 2002 and June 2003. The staff requested, in RAI 2.4.12-1, that the applicant update this figure with piezometer data from June 2003 to September 2003 and piezometer data before December 2002, if they exist, or explain how this span of data represents the seasonal variation in ground water levels. The staff also asked the applicant to explain how the ESP subsurface investigation program is consistent with previous ground water measurements. In its response, the applicant stated that it would update SSAR Table 2.4-15 and Figure 2.4-15 to include ground water level measurements taken at the North Anna site on September 29, 2003. The applicant also concluded that the quarterly measurements recorded for the ESP application appear to generally reflect the magnitude of ground water level fluctuation on a yearly basis. Further, the applicant noted that maximum ground water level fluctuations are likely to occur over much longer periods of time and may be about 60 percent greater than those measured during the 1-year ESP recording period.

2.4.12.2 Regulatory Evaluation

Section 1.8 of the SSAR presents a detailed discussion of the applicant's conformance to NRC regulations and regulatory guidance. The applicant identified the applicable regulations as 10 CFR 52.17(a), 10 CFR 100.20(c), 10 CFR 100.23, and 10 CFR 100.23(c) and the applicable regulatory guidance as RGs 1.27, 1.29, and 1.70, as well as RS-002. The staff reviewed this portion of the application for conformance with the applicable regulations, and considered the corresponding regulatory guidance, as identified above.

Acceptance criteria for this section relate to the following regulations and criteria:

- 10 CFR Parts 52 and 100 require that hydrologic characteristics be considered in the evaluation of the site.
- 10 CFR 100.23 sets forth the criteria to determine the suitability of design bases for a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the proposed site with respect to seismic characteristics of the site. It also requires that siting factors, including the cooling water supply, be evaluated, taking into account information concerning the physical, including hydrological, properties of the materials underlying the site.

As specified in 10 CFR 100.20(c), the site's physical characteristics (including seismology, meteorology, geology, and hydrology) must be considered when determining its acceptability for a nuclear power reactor.

The regulation at 10 CFR 100.20(c)(3) requires that factors important to hydrological radionuclide transport be addressed using onsite characteristics. Pursuant to the hydrologic requirements of 10 CFR Part 100, the SSAR should describe ground water conditions at the proposed site and how the construction and operation of a nuclear power plant or plants of a specified type that might be constructed on the site will affect those conditions. Meeting this guidance provides reasonable assurance that the release of radioactive effluents from a plant or plants of a specified type that might be constructed on the proposed site will not significantly affect ground water at or near a proposed site.

The regulation at 10 CFR 100.23 requires that geologic and seismic factors be considered when determining the suitability of the site for each nuclear power plant. In particular, 10 CFR 100.23(d)(4) requires that such factors as the physical properties of materials underlying the site and cooling water supply be evaluated. The regulation at 10 CFR 100.23 is applicable to SSAR Section 2.4.12 because it addresses requirements for investigating the hydrologic conditions at and near the site.

Meeting this guidance provides reasonable assurance that the effects of a safe-shutdown earthquake would pose no undue risk to the type of facility proposed for the site.

For those cases in which a reactor design is not specified, the ESP applicant may instead provide a PPE to characterize a facility or facilities for comparison with the hydrologic characteristics of the site. A PPE can be developed for a single type of facility or a group of candidate facilities by selecting limiting values of the relevant parameters.

To determine whether the applicant met the requirements of the hydrologic aspects of 10 CFR Parts 52 and 100, the staff used the following specific criteria:

- A full, documented description of regional and local ground water aquifers, sources, and sinks is necessary. In addition, the type of ground water use, wells, pump, and storage facilities, as well as the flow needed for a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the site, should be described. If ground water is to be used as an essential source of water for safety-related equipment, the design basis for protection from natural and accident phenomena should be compared with the RG 1.27 guidelines. Bases and sources of data should be adequately described and referenced.

- A description of present and projected local and regional ground water use should be provided. Existing uses, including amounts, water levels, location, drawdown, and source aquifers should be discussed and tabulated. Flow directions, gradients, velocities, water levels, and effects of potential future use on these parameters, including any possibility for reversing the direction of ground water flow, should be indicated. Any potential ground water recharge area within the influence of a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the site and the effects of construction, including dewatering, should be identified. The influence of existing and potential future wells with respect to ground water beneath the site should also be discussed. Bases and sources of data should be described and referenced. References 6 through 12 of RS-002 discuss certain studies concerning ground water flow problems.

- The need for and extent of procedures and measures to protect present and projected ground water users, including monitoring programs, should be discussed. These items are site specific and will vary with each application.

2.4.12.3 Technical Evaluation

As set forth below, the staff determined that the SSAR adequately describes onsite and offsite ground water use. The site is located adjacent to Lake Anna. Lake Anna and other water bodies exist between the ESP site and the nearest offsite ground water users. This spatial relationship and the relatively small withdrawal rates, both onsite and offsite, contribute to the hydrological isolation of the ESP site from offsite ground water users.

The applicant conducted slug tests in the newly installed wells to provide estimates of saturated hydraulic conductivities. The staff determined that the method the applicant used, as set forth in the SSAR, to estimate the saturated hydraulic conductivities (i.e., the Bouwer-Rice method) is appropriate because this is a well-established method that is widely accepted in standard engineering practice. While the estimate of hydraulic conductivity derived with the Bouwer-Rice method is appropriate for shallow unconsolidated strata, the failure to satisfy the constraints of the Bouwer-Rice method in well tests in the deeper consolidated strata is consistent with conditions in which the movement of water is limited to flow in fractures. The hydraulic conductivities in the shallow unconsolidated strata will bound the dominant subsurface transport pathways, because ground water flow in deeper consolidated strata can only pass through fractures and fissures.

Observed increases in water levels in the new wells ranged from less than 1 ft to more than 3 ft over the period of December 17, 2002, through June 17, 2003. The applicant included previously existing wells monitored at the same time in the analysis. The observed variation in water levels in wells could be significant but represents only a 6-month period. The staff evaluated additional information the applicant provided in response to RAI 2.4.12-1 but found that it needed additional data to determine whether the new ground water level measurements correlate with data from the long-term piezometers. Ground water measurements should contain at least 1 full year of data to determine recent seasonal fluctuation in ground water levels at the ESP site. The staff was also concerned that the ground water measurements provided by the applicant may have been made too soon following the 2001-2002 drought, and may still show some influence of the drought as the ground water elevations recovered near their pre-drought levels. This was Open Item 2.4-7.

In response to Open Item 2.4-7, the applicant provided additional ground water measurements to the staff in its March 3, 2005, submittal. The applicant provided another set of ground water elevations previously measured on September 29, 2003. This additional set, along with the ground water elevation measurements on December 17, 2002, March 17, 2003, and June 17, 2003 represented the seasonal variation in ground water elevations at the ESP site on a quarterly basis. The applicant also carried out a new set of ground water measurements on February 1, 2005, in nine observation wells and ten piezometers. In addition to the ground water measurements, the applicant also provided the water surface elevation in Lake Anna on February 1, 2005. Based on this additional measurement, the staff concludes that ground water elevations measured during the 2002-2003 water year did not show influences of the 2001-2002 drought, and were therefore suitable for characterization of ground water elevations and gradients at the ESP site. The applicant estimated a horizontal hydraulic gradient of 0.029 ft/ft from the center of the ESP site footprint to Lake Anna based on February 1, 2005, measurements. Since this estimate is slightly smaller than applicant's estimate of 0.03 ft/ft presented previously in the SSAR, the applicant concluded that the horizontal hydraulic gradient was not underestimated because of the 2002 drought.

Based on the additional ground water data, the staff verified the horizontal ground water gradient estimated by the applicant. The staff used the difference between the ground water elevation measured at observation well OW-846 and the water surface elevation of Lake Anna on February 1, 2005, to estimate a horizontal hydraulic gradient of 0.023 ft/ft based on an estimated distance of 1160 ft from observation well OW-846 to Lake Anna. Since the applicant's estimate of the horizontal hydraulic gradient is greater, and therefore more conservative than that estimated by the staff, it is deemed acceptable. The staff also determined that the additional data describing seasonal variations of well water elevations presented in the applicant's February 1, 2005, response adequately characterize seasonal fluctuations in ground water levels at the ESP site.

Based on the above review, the staff considers Open Item 2.4-7 to be resolved.

Ground water discharge to streams and to Lake Anna is significant, ranging from 32 to 67 percent of streamflow, according to several studies conducted in the province cited by Trapp and Horn. The staff was unable to independently estimate the ground water flowpath from the powerblock of the proposed additional units to Lake Anna since the applicant did not initially provide the precise location of the powerblock. In the following assessment, the staff used applicant-provided values for effective porosity and distance from the powerblock to Lake Anna.

The staff used the following relationship to determine average ground water velocity:

> Velocity = Hydraulic Gradient x Saturated Hydraulic Conductivity/Effective Porosity

The applicant used the geometric mean of the measured hydraulic conductivity values (1.3 ft/d). Use of the geometric mean is not conservative because it results in slower ground water velocity and increased travel time to the environment. Using 3.4 ft/d (SSAR Section 2.4.12.1.2) as the conservative value for hydraulic conductivity, 3 ft/100 ft as the hydraulic gradient, and 0.33 as the effective porosity, the staff estimated the ground water velocity to be 0.31 ft/d, as opposed to 0.12 ft/d as reported by the applicant. The staff's calculated travel time from the powerblock to the lake, using 1800 ft as the distance to the environment, is approximately 16 years, as opposed to the applicant's estimate of 40 years. In the DSER, the staff indicated that the applicant needed to explain why it did not use a more conservative hydraulic conductivity. This was Open Item 2.4-8. The staff intends to identify hydraulic conductivity as a site characteristic in any ESP that the NRC might issue for this application.

In response to Open Item 2.4-8, the applicant agreed in its March 3, 2005, submittal, to use the conservative value of 3.4 ft/d for hydraulic conductivity as the site characteristic. This value is conservative because it is the maximum hydraulic conductivity calculated for the saprolite, for which conductivity ranges from about 0.2 to 3.4 ft/d. The generally accepted industry practice is to use the average hydraulic conductivity of the saprolite. Based on the applicant's response, the staff considers Open Item 2.4-8 resolved.

The applicant's response to RAI 2.4.1-1 includes a figure that lists the coordinates of the corners of the ESP PPE (site footprint). However, as discussed in Section 2.4.1.3 of this SER, the staff indicated in the DSER that it needed additional information regarding the reference system and the units of these coordinates to determine the distance from the powerblock to the lake. Consequently, the staff identified the need for information on the coordinate system for the ESP site boundaries in Open Item 2.4-1. This open item was resolved when the applicant provided the coordinates of the corners of the ESP PPE (ESP site footprint) which is based on the North Anna plant site coordinate reference system. The coordinate system units are "feet."

The applicant proposed a site characteristic of ground water elevation less than 270 ft MSL, and it proposes an ESP plant grade (PPE value) of 271 ft MSL. The applicant identified the general location of the proposed additional units in Figure 2.4-16. Based on the ground water level data presented in SSAR Figure 2.4.16 and the UFSAR, the staff concludes that the applicant's design elevations are adequate from the perspective of the location of the water table, if the proposed additional units are constructed within the area where the ground water levels do not exceed 270 ft MSL. The staff intended this requirement, proposed in DSER Permit Condition 2.4-12, to constrain the location of the proposed units toward the northeast corner of the proposed footprint. Ground surface elevations at the ESP site generally increase from its northeast corner near Lake Anna to the southwest. As described in the SSAR, the ground water levels also approximately follow the undulations of the ground surface, varying from about 250 ft MSL near Lake Anna in the northeast corner of the ESP site footprint to over 300 ft MSL near the southwest corner. The ground water levels at the ESP site footprint could rise as high as 1 ft below the ground surface. The maximum elevation of ground water is a site characteristic and the value is set at 270 ft MSL or 1 ft below the free surface, whichever is higher. The staff determined that it is unnecessary to impose DSER Permit Condition 2.4-12 since it will review and evaluate any future plant design in accordance with NRC regulations and regulatory guidance to ensure the safety of any future plant that may be constructed within the ESP site footprint.

With respect to 10 CFR 100.23(d), the applicant is not proposing to use ground water for cooling water. Accordingly, hydraulic conditions in groundwater are of no concern with respect to cooling water supplies.

2.4.12.4 Conclusions

As set forth above, the applicant has provided sufficient information pertaining to ground water. Therefore, the staff concludes that, the applicant has met the requirements related to ground water in 10 CFR 52.17(a), 10 CFR 100.23, and 10 CFR 100.20(c)(3).

2.4.13 Accidental Releases of Liquid Effluents to Ground and Surface Waters

The North Anna site is located within the Piedmont Physiographic Province in an area underlain by crystalline bedrock. The powerblock for the proposed additional units would be sited on soil disturbed during construction of the now-abandoned NAPS Units 3 and 4.

2.4.13.1 Technical Information in the Application

In SSAR Section 2.4.13, the applicant stated that all analysis of accidental releases to ground and surface waters would be deferred to the COL stage. However, pursuant to 10 CFR 52.17(a)(1) and 10 CFR 100.20(c)(3), the applicant is required at the ESP stage to obtain factors for applicable hydrological radionuclide release pathways for a site-suitability determination. The staff requested, in RAI 2.4.13-1, that the applicant provide a conceptual model of the subsurface environment, with reference to drill logs, as-built fill, and compaction plans. The staff stated that the subsurface conceptual model should provide estimates, and the basis for these estimates, for the hydraulic conductivity of the soil, surface recharge rates, soil and ambient ground water chemical properties, and piezometric boundary conditions. In its response, the applicant stated that it developed a conceptual model of the subsurface for the ESP site, based primarily on data presented in the ESP application and supplemented by other published data. The applicant obtained data included in the ESP application from site-specific subsurface investigations and from published sources.

The applicant stated that the ground surface at the existing units and some parts of the ESP site are located at an elevation of 271 ft MSL. The ground surface rises to an elevation of over 300 ft MSL to the west and to the south of the ESP site. The ESP site is filled with fabricated material, residual soil, or saprolite. The powerblock area of the abandoned Units 3 and 4 was partially filled. The applicant stated that existing fill and residual soil would be removed from the ESP site before any future construction.

The applicant stated that saprolite overlies bedrock at the NAPS site. Based on drilling results at the site, saprolite ranges in thickness from 2 to 102 ft. The saprolite at the NAPS site varies in its lithology (structure, composition, color, and texture), depending on its parent material and its degree of weathering, and it may be classified into the categories of sand, silty sand, clayey sand, sandy silt, clayey silt, and clay. The bedrock beneath the ESP site, which belongs to Cambrian (about 500-540 million years (Ma) ago) and Ordovician age (about 443-490 Ma) Ta River Metamorphic Suite, is at depths ranging from 8 to 49 ft and consists of mostly quartz gneiss with variable weathering with joints and fractures. These joints and fractures have clay filling.

The applicant stated that ground water beneath the ESP site occurs in unconfined conditions, both in saprolite and in bedrock. Saprolite and bedrock are hydrologically connected to each other. The applicant measured potentiometric head difference between the bedrock and the saprolite at only one location (between wells OW-845 and OW-846 in Figure 5 of Dominion, "Supplemental Response to Request for Additional Information No. 4," August 19, 2004. The measured head difference is 0.3 ft, with an upward hydraulic gradient.

The applicant prepared a piezometric head contour map (Figure 5 of the same RAI response) using ground water levels measured in March 2003. The applicant concluded from this contour map that ground water flow across the ESP site is to the north and east towards Lake Anna, with a hydraulic gradient of about 0.03 ft/ft. The applicant stated that this gradient is expected to be typical of ground water flow at the ESP site, despite seasonal and long-term fluctuations caused by the controlling influence of Lake Anna and surrounding drainages.

The applicant provided a conceptual hydrogeologic model based on site investigation. The primary system for migration of radionuclides is ground water flow in unconsolidated deposits (i.e., the saprolite) and in the bedrock. Ground water in saprolite is stored and is transmitted through the pore spaces. In the crystalline bedrock, ground water is stored and is transmitted through joints and fractures. The number, extent, and opening width of joints and fractures are expected to decrease with depth, thus limiting significant water transmission in the bedrock to its upper few hundred feet.

The applicant stated that recharge to the aquifers at the NAPS site occurs largely as infiltration of rainfall and snowmelt. Average annual precipitation in the NAPS area is about 44 in., and average annual recharge is estimated to be 8 to 10 in. A minor source of recharge to the ground water at the NAPS site is the clay-lined service water reservoir for the existing NAPS units. Infiltration of water from the service water reservoir locally alters ground water levels. A series of underdrains beneath the existing pumphouse for Units 1 and 2 controls ground water levels, as well. Some ground water discharge occurs through the five active water supply wells and four minor wells, and some evapotranspiration occurs at the foundation area for the abandoned Units 3 and 4.

The applicant stated that ground water underlying the ESP site is expected to be in hydrologic connection with Lake Anna. Therefore, the water level in Lake Anna serves as a piezometric boundary condition for ground water flow towards the lake. The ground water flow at the ESP site discharges to Lake Anna and the WHTF. The applicant stated that a ground water divide is expected to exist upgradient of the ESP site and to approximately coincide with the topographic divide.

The applicant stated that no site-specific data are available to determine the chemical characteristics of ground water at the ESP site. The applicant assumed that the water quality of crystalline aquifers in the Piedmont Physiographic Province is representative of the water quality at the ESP site.

The applicant stated that, in case of an accidental release of liquid radioactive material at the ESP site, the contaminants will infiltrate to the ground water table and then flow laterally with regional ground water flow towards Lake Anna and the WHTF. Depending upon the location of the accidental release with respect to water supply wells, contaminants may impact some wells. The applicant stated that no offsite ground water users would be impacted as a result of the direction of ground water flow and the presence of ground water boundary conditions between the ESP site and these users. Finally, the applicant stated that a detailed numerical model will be developed as part of any COL application to be submitted for the proposed ESP site.

2.4.13.2 Regulatory Evaluation

Section 1.8 of the SSAR presents a detailed discussion of how the applicant proposes to conform to NRC regulations and regulatory guidance. The applicant identified the applicable regulations as Appendix B, "Annual Limits on Intakes (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage," to 10 CFR Part 20, "Standards for Protection Against Radiation," and 10 CFR Part 100 and the applicable regulatory guidance as RGs 1.27, 1.70, and 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I," Revision 1 dated April 1977 as well as RS-002. The staff reviewed this portion of the application for conformance with the applicable regulations, and considered the corresponding regulatory guidance, as identified above.

Acceptance criteria for this section relate to 10 CFR Parts 52 and 100, as they require the evaluation of the hydrologic characteristics of the site with respect to the consequences of the escape of radioactive material from the facility.

The regulations in 10 CFR Parts 52 and 100 require that local geological and hydrological characteristics be considered when determining the acceptability of a nuclear power plant site. The geological and hydrological characteristics of the site may have a bearing on the potential consequences of radioactive materials escaping from a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the proposed site. Special precautions should be planned if a reactor or reactors were to be located at a site where a significant quantity of radioactive effluent could accidentally flow into nearby streams or rivers or find ready access to underground water tables.

These criteria apply to SSAR Section 2.4.13 because site hydrologic characteristics are evaluated with respect to the potential consequences of radioactive materials escaping from a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the proposed site. The staff reviews radionuclide transport characteristics of ground water and surface water environments with respect to accidental releases to ensure that current and future users of ground water and surface water are not adversely affected by an accidental release from a nuclear power plant or plants of a specified type (or falling within a PPE) that might be constructed on the proposed site. RGs 1.113 and 4.4, "Reporting Procedure for Mathematical Models Selected to Predict Heated Effluent Dispersion in Natural Water Bodies," issued May 1974, provide guidance in selecting and using surface water models for analyzing the flowfield and dispersion of contaminants in surface waters.

Meeting the requirements of 10 CFR Parts 52 and 100 provides reasonable assurance that accidental releases of liquid effluents to ground water and surface water, and their adverse impact on public health and safety, will be minimized.

For those cases in which a reactor design is not specified, the ESP applicant may instead provide a PPE to characterize a facility or facilities for comparison with the hydrologic characteristics of the site. A PPE can be developed for a single type of facility or a group of candidate facilities by selecting limiting values of the relevant parameters.

To determine whether the applicant met the requirements of 10 CFR Parts 52 and 100 with respect to accidental releases of liquid effluents, the staff used the following specific criteria:

- Radionuclide transport characteristics of the ground water environment, with respect to existing and future users, should be described. Estimates and bases for coefficients of dispersion, adsorption, ground water velocities, travel times, gradients, permeabilities, porosities, and ground water or piezometric levels between the site and existing or known future surface water and ground water users should be described and should be consistent with site characteristics. Potential pathways of contamination to ground water users should also be identified. Sources of data should be described and referenced.

- Transport characteristics of the surface water environment, with respect to existing and known future users, should be described for conditions that reflect worst-case release mechanisms and source terms, so as to postulate the most pessimistic contamination from accidentally released liquid effluents. Estimates of the physical parameters necessary to calculate the transport of liquid effluent from the points of release to the site of existing or known future users should be described. Potential pathways of contamination to surface water users should be identified. Sources of information and data should be described and referenced. Acceptance is based on the staff's evaluation of the applicant's computational methods and the apparent completeness of the set of parameters necessary to perform the analysis.

- Mathematical models are acceptable to analyze the flowfield and dispersion of contaminants in ground water and surface water, providing that the models have been verified by field data and that conservative site-specific hydrologic parameters are used. Furthermore, conservatism should be the guide in selecting the proper model to represent a specific physical situation. Radioactive decay and sediment adsorption may be considered, if applicable, providing that the adsorption factors are conservative and site specific. RG 1.113 provides guidance in selecting and using surface water models. References 7 through 15 of RS-002 discuss the transport of fluids through porous media.

2.4.13.3 Technical Evaluation

As originally submitted, SSAR Section 2.4.13 did not contain an analysis of accidental releases to ground and surface waters, which the staff needs to evaluate currently applicable hydrological accidental radionuclide release pathways. In the DSER, the staff indicated that the applicant should provide a conceptual model of the subsurface environment, with reference to drill logs, as-built fill, and compaction plans. The staff indicated further that the subsurface conceptual model should provide estimates, and the basis for these estimates, for the hydraulic conductivity of the soil, surface recharge rates, soil and ambient ground water chemical properties, and piezometric boundary conditions. In RAI 2.4.13-1, the staff stated that these model attributes were necessary for the staff to conduct a site-suitability evaluation in accordance with RG 1.113 and requested the applicant to provide this information.

In its response, the applicant provided details of the hydrogeologic characteristics at the ESP site, including a conceptual model of ground water movement through the saprolite and the bedrock underlying the ESP site.

The applicant reported that the only observation of piezometric head difference made between the saprolite and the bedrock indicates an upward hydraulic gradient. The staff needed to understand the implications of an upward hydraulic gradient, with respect to the transport of effluents to the environment. Therefore, it requested that the applicant provide more details about the magnitude, frequency, and spatial location of these upward hydraulic gradients at the ESP site. This was Open Item 2.4-9. The staff intended to identify upward hydraulic gradient as a site characteristic in any ESP that might be issued for this application.

In its response to Open Item 2.4-9 dated March 3, 2005, the applicant characterized the significance of the upward hydraulic gradient between the bedrock and the saprolite as they relate to transport of effluent in the environment by comparing the vertical component of ground water velocity to its horizontal component.

The applicant estimated the vertical hydraulic conductivity assuming that the anisotropy ratio (K_h:K_v) is 3:1, where K_h and K_v refer to horizontal and vertical hydraulic conductivities for the subsurface. Based on this assumption and the geometric mean of the measured horizontal hydraulic conductivity values (1.3 ft/d) for the saprolite, the applicant used the ground water elevation measurements at observation wells OW-845 and OW-846 to estimate a vertical seepage velocity range between 0.006 and 0.019 ft/d. The corresponding estimate for the horizontal seepage velocity is 0.12 ft/d. The applicant estimated that the vertical seepage velocity is about 5 to 15 percent of the horizontal seepage velocity and argued that the vertical hydraulic gradient between the bedrock and saprolite at the ESP site is of minor significance with respect to the transport of effluent in the environment.

The staff reviewed the applicant's approach for ascertaining the significance of the vertical hydraulic gradient on the transport of effluent in the subsurface. The applicant's justification of the relatively minor significance of the upward hydraulic gradient is based on the assumed anisotropy ratio (K_h:K_v) of 3:1 that was used to estimate the vertical hydraulic conductivity and, subsequently, the vertical component of seepage velocity. Because not enough evidence points to layering (such as horizontal clay lenses) within the saprolite that underlies the ESP site, the staff could not find a justification for the applicant's assumed anisotropy ratio. However, the bedrock has a significantly lower hydraulic conductivity and also a significantly lower porosity as compared to the overlying saprolite. Therefore, the staff concluded that, even if the subsurface hydraulic conductivity were isotropic (i.e., a K_h:K_v of 1:1, leading to a more conservative vertical hydraulic conductivity than the applicant's estimate) at the ESP site, the amount of upward flow out of the bedrock into the saprolite would be small compared to the nearly horizontal regional ground water flow in the saprolite. Based on this reasoning, the staff considers Open Item 2.4-9 resolved.

The applicant stated that the typical hydraulic gradient of ground water flow across the ESP site to Lake Anna and the WHTF is 0.03 ft/ft. The applicant based this estimate on only one piezometric head contour map constructed using ground water level observations from March 2003. The applicant stated that this hydraulic gradient is typical of the ESP site, despite seasonal and long-term variation in the ground water regime. However, in the DSER, the staff indicated that the applicant should provide data to support this statement and to define the range of seasonal and long-term variation in hydraulic gradient from the ESP site into Lake Anna and the WHTF. This was Open Item 2.4-10. The staff stated that it intended to identify the hydraulic gradient from the ESP site to Lake Anna and the WHTF as a site characteristic in any ESP that might be issued for this application.

In response to Open Item 2.4-10, in its submittal dated March 3, 2005, the applicant stated that, in order to determine the range of variation in the horizontal hydraulic gradient, it prepared additional piezometric head contour maps using ground water elevations recorded at four times other than the March 2003 measurement date. The applicant stated that the configuration of piezometric head contours on all of these maps is very similar and concluded that only minor fluctuations in ground water levels were recorded between December 2002 and February 2005. The applicant estimated the horizontal hydraulic gradient from the center of the ESP site footprint near observation well OW-846 to the Lake Anna shoreline near observation well OW-848 using all five ground water level measurements. The applicant-estimated horizontal hydraulic gradients range from 0.027 to 0.029 ft/ft.

The staff verified the horizontal ground water gradient estimated by the applicant for the February 1, 2005, measurement. The staff used the difference between the ground water elevation measured at observation well OW-846 and the water surface elevation of Lake Anna on February 1, 2005, to estimate a horizontal hydraulic gradient of 0.023 ft/ft based on a staff-estimated distance of 1160 ft from observation well OW-846 to Lake Anna. Since the applicant's estimate of the horizontal hydraulic gradient is greater and therefore more conservative than that estimated by the staff, the applicant's value is deemed acceptable. The staff also determined that the additional data presented by the applicant adequately characterize the seasonal fluctuations in ground water levels at the ESP site.

Based on the applicant's response, the staff considers Open Item 2.4-10 resolved.

The site suitability evaluation, with respect to radionuclide transport characteristics as defined by 10 CFR 100.20(c)(3), requires the use of observed site-specific parameters important to hydrological radionuclide transport (such as soil, sediment, and rock characteristics; adsorption and retention coefficients; ground water velocity; and distances to the nearest surface body of water) obtained from onsite measurements. The applicant did not provide the onsite measured values of adsorption and retention coefficients for radioactive materials. This was Open Item 2.4-11. The staff intended to identify onsite measured values of adsorption and retention coefficients for radioactive materials as a site characteristic.

In response to Open Item 2.4-11, the applicant stated in its submittal dated March 3, 2005, that it obtained site-specific adsorption coefficients important to subsurface hydrological radionuclide transport from onsite measurements of soil characteristics. The applicant assembled a radionuclide inventory from information provided in the AP1000 Design Control Document, Tier 2, Table 12.2-9 (Sheet 4), for the effluent holdup tank liquid phase and waste holdup tank, and in the Advanced Boiling-Water Reactor Standard Safety Analysis Report, Table 12.2-13a, for the low conductivity waste collection tank. These documents list the radionuclides that are expected to be present in the liquid radwaste systems of the respective reactors. The applicant compiled a composite list of radionuclides and their activities using the two radwaste inventories, using the more conservative activity from the two designs.

The applicant screened the radionuclides in the composite list to identify those radionuclides that may migrate through the subsurface to the environment (Lake Anna) with a residual activity in excess of the values identified in Column 2 of Table 2 in Appendix B to 10 CFR Part 20. During this screening, the applicant assumed an instantaneous release of the radwaste inventory to the saturated zone, ignored any adsorption or retardation of the radionuclides during their migration from the point of release to Lake Anna, and accounted for the radioactive decay of the individual radionuclides in the inventory during the migration. The applicant used a travel time of 16 years for the radwaste plume to migrate from the point of release to Lake Anna based on the maximum measured hydraulic conductivity of 3.4 ft/d, a horizontal hydraulic gradient of 0.03 ft/ft, an effective porosity of 0.33, and an estimated travel distance of 1800 ft from the point of release to Lake Anna. The applicant selected all radionuclides that retained a residual activity in excess of values identified in Column 2 after 16 years of decay during migration to the lake. For these radionuclides, iron (Fe)-55, cobalt (Co)-60, strontium (Sr)-90, cesium (Cs)-134, and Cs-137, the adsorption (distribution) coefficient was considered important to subsurface hydrological transport.

The applicant stated that it obtained distribution coefficients for each of the selected radionuclides from published values based on the measured physical and chemical soil properties at the ESP site. The applicant obtained distribution coefficients for Co and Fe from Sheppard and Thibault (1990) by selecting a soil type that yielded the most conservative (lowest) value. It obtained the distribution coefficients for Cs and Sr from EPA (1999). The applicant also included manganese (Mn), ruthenium (Ru), and zinc (Zn) in its analysis to account for the fact that the travel time from the point of release to the lake could be less than 16 years if the release occurred near the edge of the ESP site footprint closest to Lake Anna. The applicant obtained the distribution coefficients for Mn, Ru, and Sr from Sheppard and Thibault (1990). The applicant presented the values of the distribution coefficient for eight radionuclides in a table included in its submittal dated March 3, 2005.

The staff reviewed the applicant's response to Open Item 2.4-11 and identified three major issues regarding subsurface migration of radionuclides released accidentally in the ground water to the accessible environment (Lake Anna and the WHTF). The first issue is the composition of the radionuclide inventory and selection of specific radionuclides from the inventory that may be critical to public health and safety. A description of the staff's evaluation of the applicant's approach to the selection of specific radionuclides follows. The second issue is the definition or delineation of potential subsurface pathways from the point of release to the accessible environment. The third issue is related to the uncertainty of subsurface hydrological properties that may affect the migration of the radionuclides.

Selection of Specific Radionuclides

Section 2.4.13 of RS-002 outlines the review of accidental radioactive liquid effluent releases as they may affect existing and known future uses of ground water and surface water resources. The guidance calls for evaluation of transport capabilities and potential subsurface contamination pathways under accident conditions to determine the most adverse scenarios for contamination of ground water or of surface waters via subsurface pathways. RS-002 states that *concentrations of radionuclides in the body of water under consideration should be* estimated based on dispersion computations with initial concentrations determined for the most critical event. Final estimated concentrations in the radioactive effluent at the points of interest should be within acceptable limits as prescribed by Column 2 of Table 2 in Appendix B to 10 CFR Part 20.

According to 10 CFR Part 20, which prescribes standards for protection against radiation, total ionizing radiation dose to an individual, including doses resulting from licensed and unlicensed radioactive material and from radiation sources other than background radiation, must not exceed the standards for protection. The effluent concentration values given in Column 2 are equivalent to the radionuclide concentrations that, if ingested continuously for a year, would produce a total effective dose equivalent of 0.05 rem (50 millirem or 50 millisieverts). The staff concludes that, because of the presence of several radionuclides in the potential accidental release, an individual near a contaminated point of interest would receive a cumulative ionizing radiation dose from each radionuclide that constitutes the effluent. For this reason, the staff has determined that the applicant's screening procedure for selecting the radionuclides of importance to subsurface hydrological transport may be inappropriate. In the staff's view, the dose calculations must include all radionuclides that may reach Lake Anna or the WHTF via a subsurface pathway in order to estimate the total dose to an individual using these waters.

Subsurface Pathways to Accessible Environment

The applicant used a distance of 1800 ft from the point of release to Lake Anna to estimate the time of travel for regional ground water flow. Since the nuclear power plant design has not been selected at the ESP stage and no details regarding the location of an accidental radioactive material release are available, the staff concludes that it is not possible at the ESP stage to delineate all possible subsurface pathways at the ESP site and to evaluate the potential pathways to determine the most critical event. In the staff's view, all subsurface pathways from the final location of the release point to Lake Anna and the WHTF should be delineated once the plant design has been selected. More detailed hydrologic measurements may be necessary at that point to characterize the subsurface properties along these pathways to establish the most critical event.

Uncertainty of Subsurface Hydrological Properties

Several subsurface hydrological properties influence the migration of the radionuclide plume in the ground water. Some of these properties include hydraulic conductivity, hydraulic gradient, and distance to the nearest point to a surface water body that are common to all radionuclides that may constitute the radwaste inventory. Some other properties such as adsorption and retention coefficients may be unique to each radionuclide. In addition, subsurface chemical properties, such as pH, may affect different radionuclides differently (EPA 1999a, 1999b, 2004). The radwaste itself may contain certain complexing agents that are frequently used in decontamination processes to remove buildup of radionuclides from cooling systems, such as one or more chelating agents including ethylenedinitrilo tetraacetic acid, picolinic acid, oxalic acid, and citric acid. The presence of these complexing agents can enhance the mobility of some radionuclides, especially transition metals (Davis et al., 2000; Serne et al., 2002). For this reason, EPA (1999b) cautions that its lookup tables do not apply to environments containing organic chelates.

The staff concludes that, because of incomplete knowledge of subsurface hydrological and chemical properties and the likely composition of the radwaste effluent itself, significant uncertainty exists in characterization of radionuclide migration in the subsurface at the ESP site at the time of ESP review. The staff has determined that, after the reactor design is selected and additional details related to radwaste tank design and the location within the proposed site are known, appropriate subsurface hydrological characterization can be completed. Therefore, at the time of a COL or CP application, more reliable estimation of radionuclide migration to surface waters via subsurface pathways can be made.

At the ESP application stage, a decision related to a specific reactor design has not been made. Therefore, the following details are not available for the staff to fully consider the effect of accidental release of liquid effluents in ground and surface waters: exact location of radwaste storage facilities, location and elevation of likely point of release, and detailed characterization of liquid pathways above and below ground from the point of release to the accessible environment. Although the staff conceptually used siting factors such as soil, sediment, and rock characteristics, adsorption and retention coefficients, ground water velocity, and distances to the nearest surface body of water in its site suitability determination, it determined that this issue could be resolved if there were no releases of radionuclides to the ground water. Accordingly, the staff proposes to include a condition in any ESP that might be issued for the North Anna site requiring that an applicant referencing such an ESP design any new unit's radwaste systems with features to preclude any and all accidental releases of radio-nuclides into any potential liquid ground water pathway. **This is Permit Condition 4.**

2.4.13.4 Conclusions

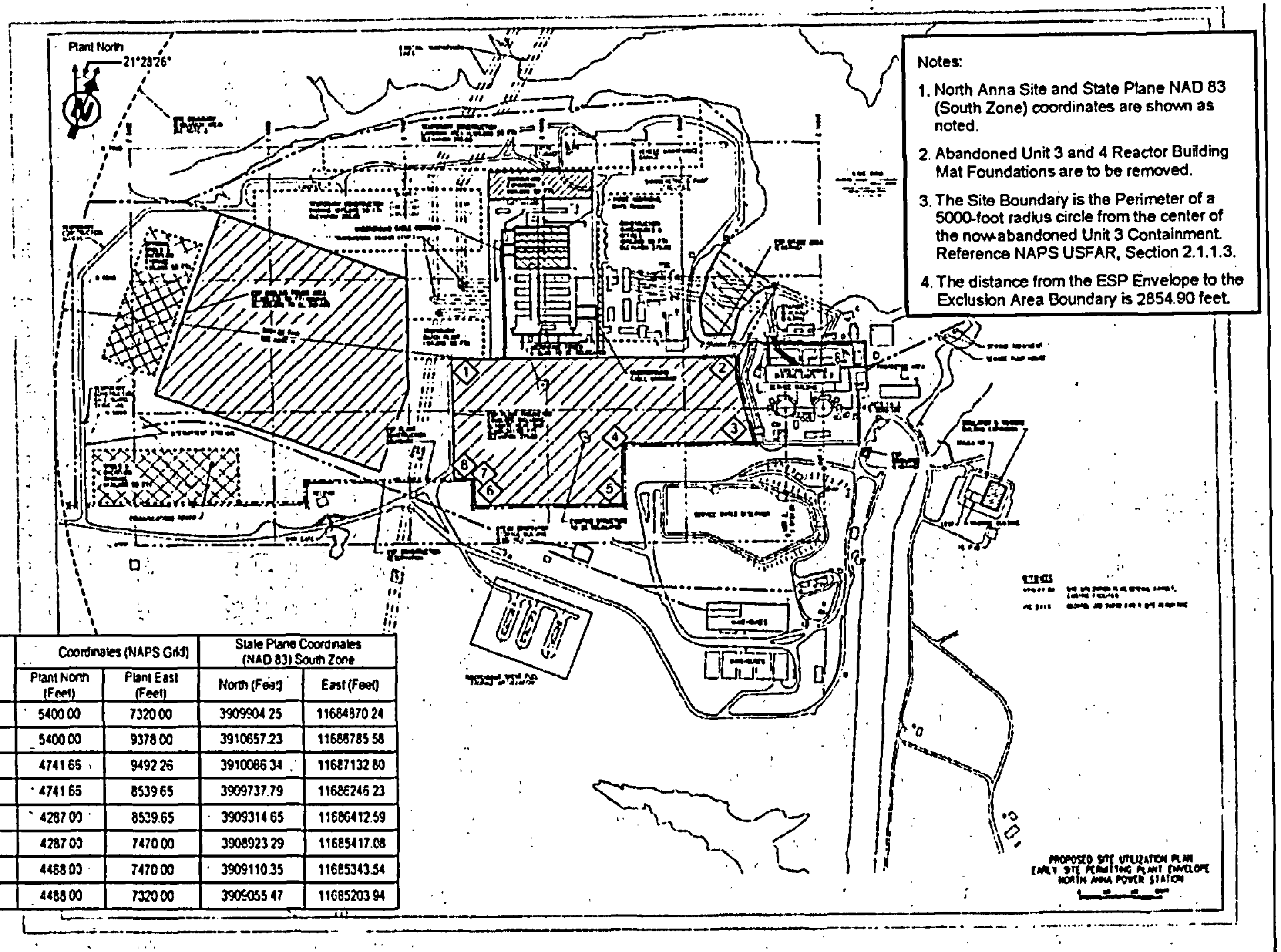
As set forth above, the applicant has provided sufficient information pertaining to liquid pathways. Therefore, the staff concludes that, with the noted conditions, the applicant has met the requirements related to liquid pathways of 10 CFR 52.17(a) and 10 CFR 100.20©(3).

2.4.14 Site Characteristics Related to Hydrology

Based on its review of SSAR Section 2.4, the staff has determined that any ESP that might be issued for the proposed site should include the site characteristics given in Table 2.4.14-1.

Table 2.4.14-1 Staff's Proposed Site Characteristics Related to Hydrology

SITE CHARACTERISTIC	VALUE
Proposed Facility Boundaries	Figure 2.4.14-1 shows the proposed facility boundary using its corners numbered 1–8 and also lists the geographical coordinates of these points in Virginia State Plane Coordinate System using NAD 83 Datum. The coordinates are expressed in feet.
Minimum Lake Water Level	242 ft MSL
Maximum Elevation of Ground Water	270 ft MSL or 1 ft below the free surface, whichever is higher
Flood Elevation	270 ft MSL
Local Intense Precipitation	18.3 in./hr and 6.1 in. in 5 minutes
Frazil and Anchor Ice	The ESP site has the potential for the formation of frazil and anchor ice.
Maximum Ice Thickness	17.1 in. thick
Maximum Cumulative Degree-Days Below Freezing	322 °F
Hydraulic Conductivity	3.4 ft/d
Hydraulic Gradient	0.03 ft/ft



Point	Coordinates (NAPS Grid)		State Plane Coordinates (NAD 83) South Zone	
	Plant North (Feet)	Plant East (Feet)	North (Feet)	East (Feet)
1	5400 00	7320 00	3909904 25	11684870 24
2	5400 00	9378 00	3910657.23	11685785 58
3	4741 65	9492 26	3910086 34	11687132 80
4	4741 65	8539 65	3909737.79	11686246 23
5	4287 00	8539.65	3909314 65	11686412.59
6	4287 00	7470 00	3908923 29	11685417.08
7	4488 00	7470 00	3909110.35	11685343.54
8	4488 00	7320 00	3909055 47	11685203 94

Figure 2.4.14-1 The proposed facility boundary for the ESP site

2.5 Geology, Seismology, and Geotechnical Engineering

In SSAR Section 2.5, the applicant described the geological, seismological, and geotechnical engineering properties of the ESP site. SSAR Section 2.5.1 describes the basic geologic and seismologic data for the site and region surrounding the site. SSAR Section 2.5.2 describes the vibratory ground motion at the site in terms of a probabilistic seismic hazard analysis (PSHA) and develops a site SSE ground motion. SSAR Section 2.5.3 describes the potential for surface faulting at or near the surface of the ESP site. SSAR Section 2.5.4 presents information on the stability of the site's subsurface materials. SSAR Section 2.5.5 describes the stability of slopes at the site. Finally, SSAR Section 2.5.6, which covers embankments and dams, states that the applicant did not reanalyze the North Anna Dam as part of the ESP application.

Since the ESP site is located adjacent to NAPS Units 1 and 2, abandoned Units 3 and 4, and the independent spent fuel storage installation (ISFSI), the applicant stated in SSAR Section 2.5 that it used the previous site investigations for these facilities as its starting point for the characterization of the geological, seismological, and geotechnical engineering properties of the ESP site. As such, the material in Section 2.5 of the ESP application focuses on any newly published information since the publication of the NAPS updated safety analysis report in the 1970s as well as recent geological, seismological, geophysical, and geotechnical investigations performed for the ESP site. The applicant stated that it conducted these investigations in progressively greater detail closer to the ESP site. The applicant defined the following zones of investigation around the site:

- region—within 200 miles
- vicinity—within 25 miles
- area—within 5 miles

The ESP site itself is defined as the area within 0.6 mile of the site location.

The applicant also used the seismic source and ground motion models published by the Electric Power Research Institute (EPRI) for the central and eastern United States (CEUS), "Seismic Hazard Methodology for the Central and Eastern United States," as the starting point for its seismic hazard evaluation. The applicant updated the EPRI seismic source and ground motion models in accordance with RG 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion," issued March 1997. RG 1.165 indicates that applicants may use the seismic source interpretations developed by Lawrence Livermore National Laboratory (LLNL) in the "Eastern Seismic Hazard Characterization Update," published in 1993, or the EPRI models, published in 1986, as inputs for a site-specific analysis.

2.5.1 Basic Geologic and Seismic Information

SSAR Section 2.5.1 describes the geologic and seismologic characteristics of the ESP site region and area. SSAR Section 2.5.1.1 describes the geologic and tectonic setting of the site region, and SSAR Section 2.5.1.2 describes the structural geology of the site area.

2.5.1.1 Technical Information in the Application

2.5.1.1.1 Regional Geology

SSAR Section 2.5.1.1 describes (1) the physiographic provinces that encompass a 200-mile radius of the site, (2) the geologic history in terms of the major tectonic events, (3) regional stratigraphy, (4) the regional tectonic setting, and (5) regional gravity and magnetic data.

Physiographic Provinces

SSAR Section 2.5.1.1.1 describes the regional physiography and geomorphology of the ESP site. The ESP site lies within the Piedmont physiographic province. The Piedmont province lies between the Coastal Plain province to the east and the Blue Ridge province to the west and is characterized by deeply weathered bedrock. Elevations in the Piedmont province range from 800 to 1500 ft in the western portion of the province to about 200 ft in the eastern portion, near the Coastal Plain province. Figure 2.5.1-1, reproduced from SSAR Figure 2.5-1, illustrates each of the physiographic provinces within the site region.

Regional Geologic History

SSAR Section 2.5.1.1.2 describes the geologic history of the ESP site region, which is composed of episodes of continental collisions with intervening episodes of continental rifting. Episodes of continental collisions have produced a series of accreted terranes that are separated by low-angle detachment faults. In contrast, intervening episodes of continental rifting have produced high-angle normal faults that either extend downward into the low-angle detachment faults or penetrate entirely through the accreted terranes. The latest major tectonic events in the region include the Allegheny orogeny (mountain building) and Mesozoic and Cenozoic crustal extension (rifting) episodes. The collision of the North American and African plates caused the Allegheny orogeny, which occurred during the late Carboniferous Period (about 290–330 million years (Ma) ago) and extended into the Permian Period (240–290 Ma). Crustal extension followed the Allegheny orogeny during the early Mesozoic Era (200–240 Ma) that began the opening of the Atlantic Ocean. This early Mesozoic extensional episode continued with the development of the mid-Atlantic spreading center during the Cenozoic Era (63 Ma–present). Currently, the site region is located on the passive, divergent trailing margin of the North American plate following this last episode of continental extension and rifting.

Regional Stratigraphy

Section 2.5.1.1.3 of the SSAR describes the regional stratigraphy of the ESP site. Two distinct rock types mark the regional stratigraphy of the Piedmont province. The first and oldest type is the crystalline rock of the late Precambrian (570–1500 Ma) and Paleozoic age (240–570 Ma). Overlying these rocks are Mesozoic-age (63–240 Ma) sedimentary rocks deposited locally in down-faulted basins within the crystalline rocks. Residual soils derived from weathering of the crystalline rocks, as well as Quaternary-age (2 Ma–present) alluvium and colluvium, overlay both the sedimentary and crystalline rocks.

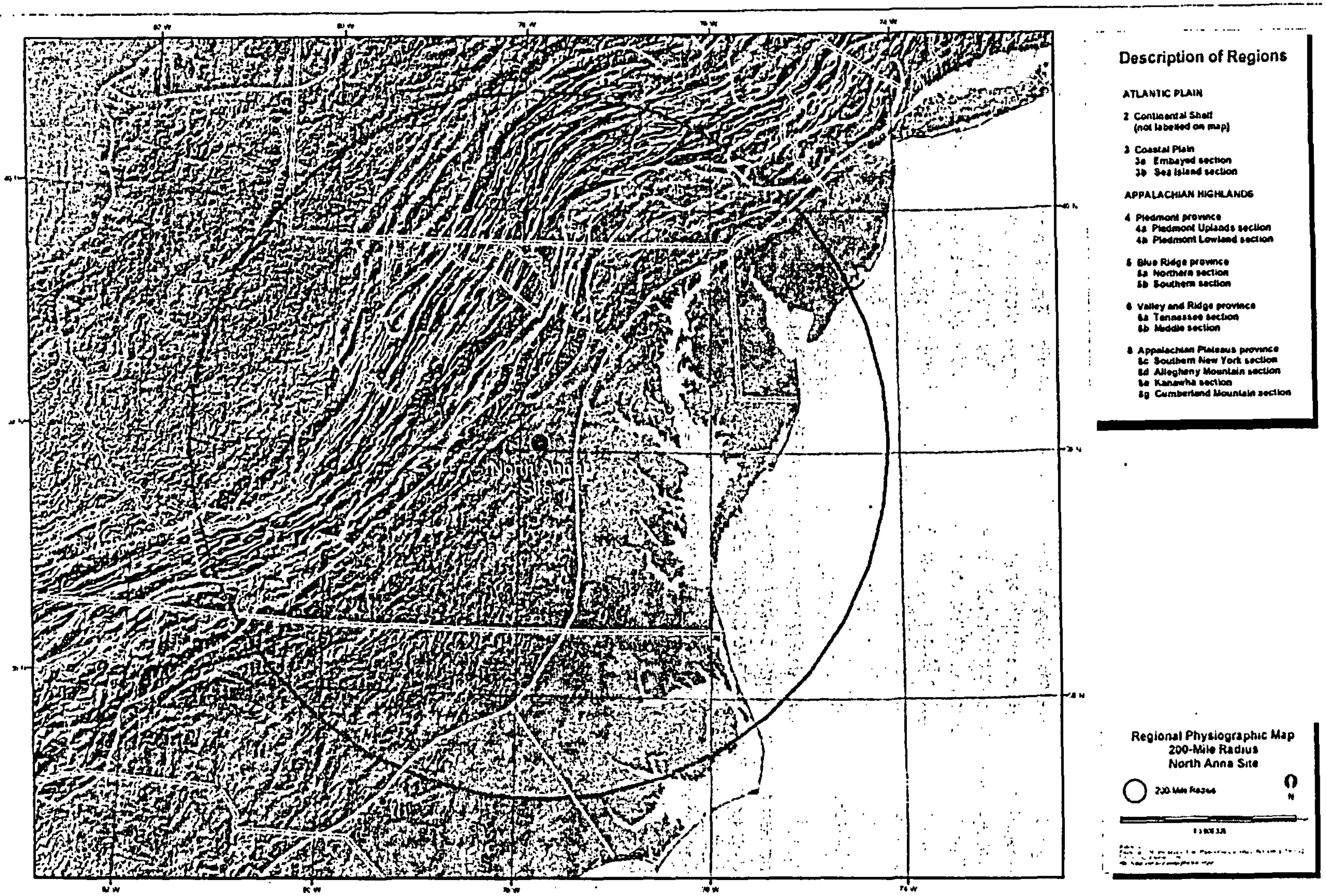


Figure 2.5.1-1 Regional physiographic map (200-mile radius)

Regional Tectonic Setting

Section 2.5.1.1.4 of the SSAR describes the regional tectonic setting for the ESP site. Figure 2.5.1-2, reproduced from SSAR Figure 2.5-5, presents a simplified tectonic and stratigraphic map of the site region, including many of the local faults.

The ESP site lies within the central Appalachian region of Virginia, which is part of the northeast-trending Appalachian orogenic belt that extends nearly the entire length of the eastern United States. The tectonic stress in the CEUS, including the Appalachian region, is primarily characterized by northeast-southwest-directed horizontal compression. The expert teams that participated in the 1986 EPRI hazard evaluation concluded that the most likely source of the tectonic stress in the CEUS region is a ridge-push body force associated with the mid-Atlantic ridge, which is transmitted to the interior of the North American tectonic plate. Studies cited in SSAR Section 2.5.1.1.4 found the magnitude of the northeast-southwest-directed stress to be about 2 to $3x10^{12}$ N/m, which corresponds to average equivalent stresses of about 40 to 60 MPa, distributed across a 30-mile-thick elastic plate.

SSAR Section 2.5.1.1.4 categorizes four principal tectonic structures within the 200-mile ESP site region based on the age of formation or reactivation of the structures, including those active during (1) the Paleozoic Era (240–570 Ma), (2) the Mesozoic Era (63–240 Ma), (3) the Tertiary Period (2–63 Ma), and (4) the Quaternary Period (2 Ma–present).

Paleozoic Tectonic Structures

The rocks and structures within the physiographic provinces that encompass the ESP site region are associated with thrust sheets that formed during the convergent Appalachian orogenic events of the Paleozoic Era (240–570 Ma). The majority of these thrust sheets are shallow and dip eastward into a low-angle, basal Appalachian decollement. Below the decollement are rocks that form the North American basement complex. The basement rocks contain normal faults that formed during the late Precambrian to Cambrian Period (570–1500 Ma). Literature cited in the SSAR states that much of the sparse seismicity in the Appalachian region occurs within this North American basement complex and not within the more abundant, shallow thrust sheets mapped at the surface.

Major Paleozoic tectonic structures near the ESP site include the Hylas shear zone, Spotsylvania thrust fault, Long Branch thrust fault, Chopawamsic thrust fault, Lake of the Woods thrust fault, and Mountain Run fault zone. No seismic activity has been attributed to any of the Paleozoic faults within 200 miles of the site, and, as such, the applicant considers none to be capable tectonic sources, as defined in Appendix A to RG 1.165. Of these tectonic structures, the Hylas shear zone, the Lake of the Woods thrust fault, and the Mountain Run fault zone are the most prominent. In response to RAI 2.5.1-4, the applicant revised SSAR Section 2.5.1.1.4 to state that there is no reported geomorphic expression, historical seismicity, or Quaternary deformation along either the Hylas shear zone or the Lake of the Woods thrust fault. Diffuse, scattered seismicity occurs throughout the Central Virginia seismic zone (CVSZ), but it is not spatially concentrated or aligned with either of these two structures. SER Section 2.5.1.3.1 provides a complete description of the applicant's response to RAI 2.5.1-4 and the staff's evaluation of the applicant's response.

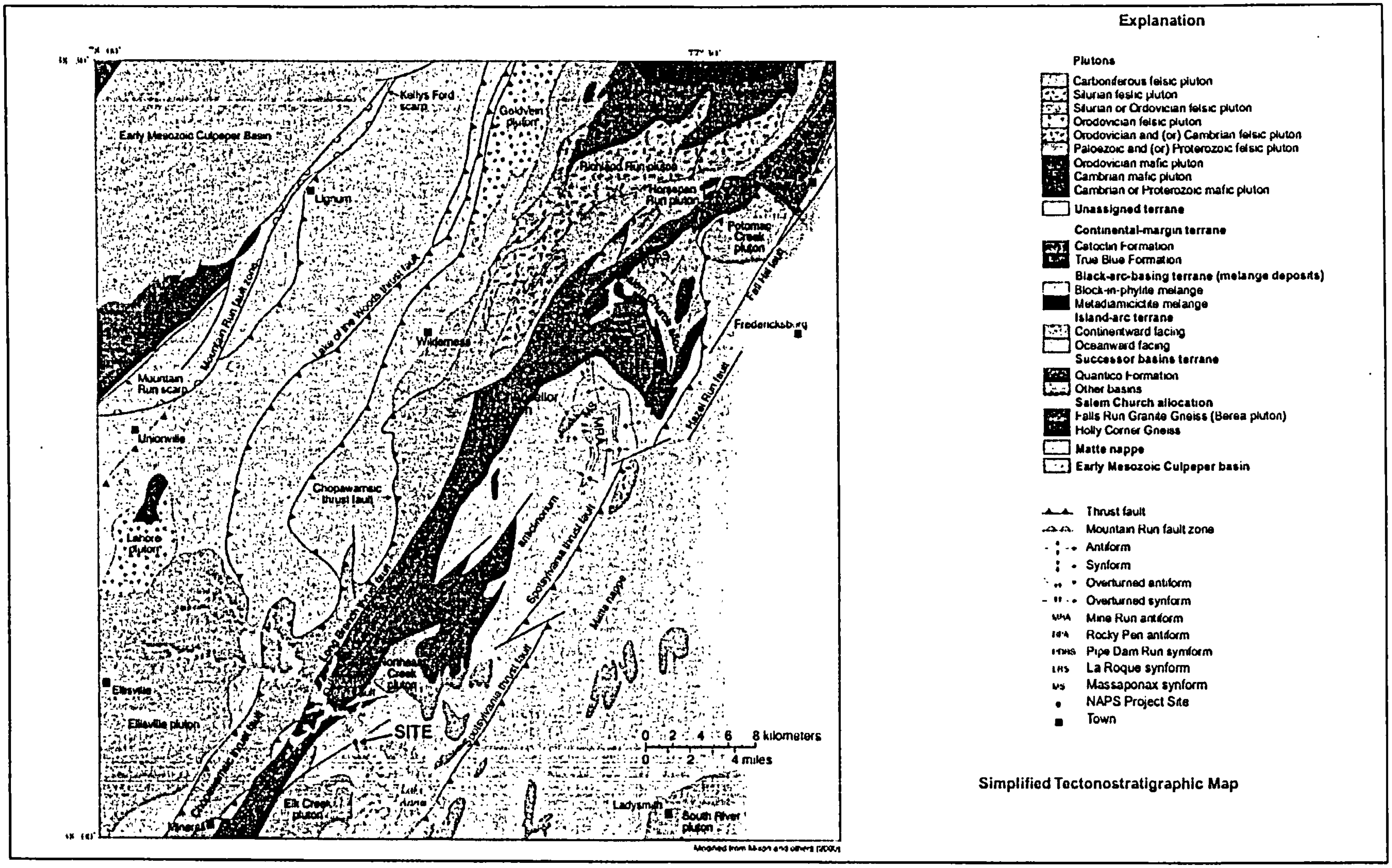


Figure 2.5.1-2 Simplified tectonostratigraphic map

Since the Mountain Run fault zone is one of the most clearly recognizable faults in the region with two pronounced scarps occurring along the fault zone, the applicant identified it as a potential Quaternary tectonic feature. SSAR Section 2.5.1.1.4 states that these two pronounced scarps along the Mountain Run fault zone have led some experts to suggest that the fault has experienced a late Cenezoic (63 Ma–present) phase of movement. The Mountain Run fault zone is a 75-mile-long fault zone that lies approximately 18 miles northwest of the site. The following excerpt from SSAR Section 2.5.1.1.4 describes the applicant's investigation of the Mountain Run fault zone:

> Field and aerial reconnaissance performed for this ESP application did not reveal any geologic or geomorphic features indicative of potential Quaternary activity along the Mountain Run fault zone. A review of 1:24,000 scale topographic maps revealed that the steeper portions of the Mountain Run scarp correlate with the areas where the Mountain Run (stream) is impinging on the scarp. In addition, the northwest side of the narrow Mountain Run valley is steepest where the stream is impinging on that side of the valley. These observations suggest that the scarp most likely formed due to erosion, as southeastward-migrating streams impinge against the more resistant rocks in the Mountain Run fault zone.

Based on the reconnaissance described above, the applicant concluded that the Mountain Run fault zone is not a capable tectonic source. In response to RAI 2.5.1-5, the applicant stated that its reconnaissance field and aerial evaluations demonstrated that the Mountain Run and Kelly's Ford scarps along the Mountain Run fault zone are associated with incised drainages that are preferentially eroding the southeast valley walls, creating asymmetric valley profiles. As such, the applicant determined that the scarps are most likely products of fluvial erosion. SER Section 2.5.1.3.1 provides a complete description of the applicant's response to RAI 2.5.1-5 and the staff's evaluation of the applicant's response.

Mesozoic Tectonic Structures

A series of elongated Mesozoic Era (63–240 Ma) rift basins are exposed in a belt extending from Nova Scotia to South Carolina. These rift basins exhibit a high degree of parallelism with the surrounding structural grain of the Appalachian orogenic belt. They were formed during the extension and thinning of the Earth's crust as Africa and North America rifted apart to form the Atlantic Ocean. Section 2.5.1.1.4 of the SSAR states that, although the Mesozoic basins have long been considered potential sources for earthquakes along the eastern seaboard, none of the basins in the site region is associated with a known capable tectonic source.

Tertiary Tectonic Structures

Tertiary Period (2–63 Ma) tectonic structures within 200 miles of the ESP site include the Brandywine fault system in Maryland, the National Zoo faults in Washington, DC, the Dutch Gap fault in Virginia, and the Stafford fault system. The Stafford fault is a 42-mile-long fault system that comes within 16.5 miles of the site. Section 2.5.1.1.4 states that the NAPS licensee's (Virginia Power's) detailed drilling, trenching, and mapping of the Stafford fault system in the Fredericksburg region in the early 1970s showed that the youngest identifiable fault movement occurred before the middle Miocene Epoch (i.e., more that 10 Ma ago). Subsequent investigations have shown some minor, later activity along the Stafford fault system. However, none of this activity has occurred during the Quaternary Period (i.e., the past 2 Ma). Thus, the applicant concluded that the Stafford fault system is not a capable tectonic source. The applicant stated that the EPRI 1986 seismic source models incorporated all of the available information on the Stafford fault system. In addition, the applicant stated that no new significant information has been developed since 1986 regarding the potential activity of the Stafford fault system. In response to RAI 2.5.1-6, the applicant stated that it based its conclusion that the Stafford fault system is not a capable tectonic source on a review of existing literature, discussions with researchers familiar with the area, areal and field reconnaissance, and geomorphic analyses. SER Section 2.5.1.3.1 provides a complete description of the applicant's response to RAI 2.5.1-6 and the staff's evaluation of the applicant's response.

Quaternary Tectonic Features

To define Quaternary tectonic (2 Ma–present) features, the applicant used the study of Crone and Wheeler (Ref. 59, SSAR Section 2.5) as one of its criteria. Crone and Wheeler compiled geologic information on Quaternary faults, liquefaction features, and possible tectonic features in the CEUS. They evaluated and classified these features into one of four categories (Classes A, B, C, and D) based on geologic evidence of Quaternary faulting or deformation. Within a 200-mile radius of the ESP site, Crone and Wheeler identified 11 potential Quaternary features. Of these 11 features, only the CVSZ showed geologic evidence that demonstrates the existence of a Quaternary fault of tectonic origin (Class A). SSAR Section 2.5.1.1.4 states that none of the other features compiled by Crone and Wheeler have "demonstrated evidence of Quaternary activity that would imply recurrent activity in the past 500,000 years." The applicant investigated many of these features, such as the Mountain Run fault zone described above, in great detail to determine their potential for Quaternary activity. Figure 2.5.1-3, reproduced from SSAR Figure 2.5-12, shows the Quaternary features identified by Crone and Wheeler.

The ESP site is located near the northern boundary of the CVSZ. Because the causative faults have not been identified, the applicant characterized the CVSZ as a seismogenic source rather than a capable tectonic source. The largest earthquake known to have occurred in the CVSZ is the body-wave magnitude (m_b) 5.0 Goochland County event in 1875. The CVSZ is an area defined by moderate to low historical seismic activity, as well as paleoseismicity, since Obermeier and McNulty recently identified two paleoliquefaction features within the CVSZ (Ref. 71, SSAR Section 2.5). However, SSAR Section 2.5.1.1.4 states that the absence of widespread paleoliquefaction led Obermeier and McNulty to conclude that an earthquake of magnitude 7 or larger has not occurred within the CVSZ in the last 2000–3000 years, or in the eastern portion of the seismic zone for the last 5000 years. In addition, the applicant stated that "these isolated locations of paleoliquefaction may have been produced by local shallow moderate magnitude earthquakes of [moment magnitude (M_w)] 5 to 6." In RAI 2.5.1-1, the staff asked the applicant to describe these two paleoliquefaction features and their impact on the seismic characterization of the CVSZ. In its response, the applicant modified SSAR Section 2.5.1.1.4 to reaffirm its conclusion that the original 1986 EPRI study adequately characterizes the magnitude level of the CVSZ. SER Section 2.5.1.3.1 provides a complete description of the applicant's response to RAI 2.5.1-1 and the staff's evaluation of the applicant's response.

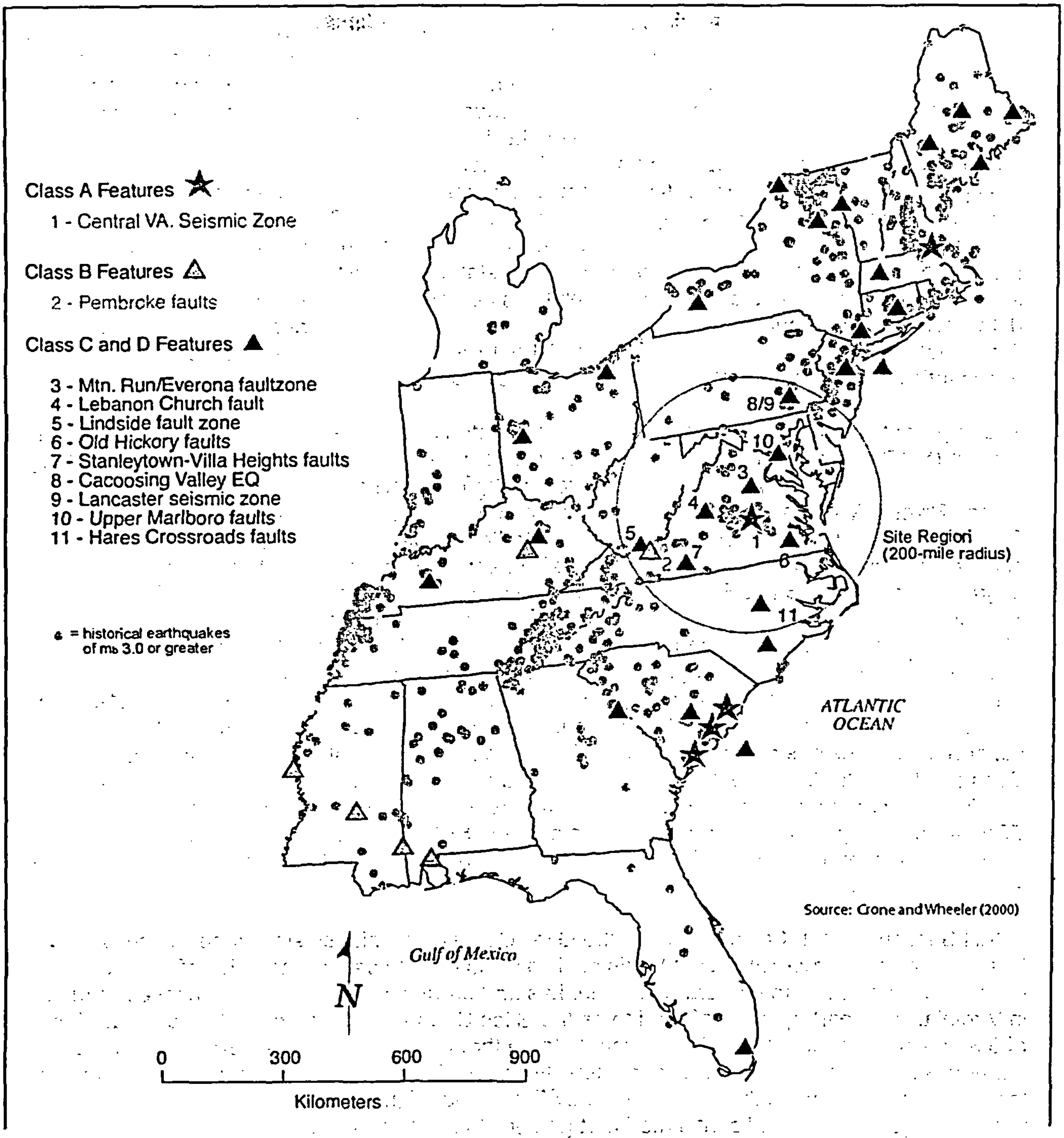


Figure 2.5.1-3 Quaternary features map

The applicant also identified the seven fall lines across the Piedmont and Blue Ridge provinces of North Carolina as another potential Quaternary tectonic feature. Weems identified these seven fall lines (Ref. 70, SSAR Section 2.5), which are based on the alignment of short stream segments with anomalously steep gradients. Because other studies of potential tectonic features in the CEUS do not include the seven fall lines identified by Weems, the applicant concluded that they do not represent a capable tectonic source. In RAI 2.5.1-3, the staff asked the applicant to more strongly justify its conclusion that the seven fall lines do not represent a capable tectonic source. In its response, the applicant revised SSAR Section 2.5.1.1.4 to strengthen its conclusion by stating that Weems does not present direct credible evidence for a tectonic origin of the fall lines. The applicant also stated that, based on its evaluation of the stratigraphic, structural, and geomorphic relations across and adjacent to the fall zones, differential erosion resulting from variable bedrock hardness is a more plausible explanation than Quaternary tectonism. SER Section 2.5.1.3.1 provides a complete description of the applicant's response to RAI 2.5.1-3 and the staff's evaluation of the applicant's response.

The applicant cited another potential Quaternary tectonic feature known as the East Coast fault system (ECFS). The ECFS is a 370-mile-long fault system that consists of three 125-mile-long segments extending from the Charleston area in South Carolina northeastward to near the James River in Virginia. The southern segment of the ECFS (ECFS-S) is associated with the Charleston earthquake of 1868 (with an estimated magnitude of about 7) and continues to show microseismic activity. Only Marple and Talwani postulated the central and northern segments of the ECFS (ECFS-C and ECFS-N) as tectonic features (Ref. 75, SSAR Section 2.5). The closest approach of the northern segment to the site is approximately 70 miles to the southeast. Because the ECFS-N and ECFS-C have not been associated with any seismicity and gravity or magnetic anomalies, the applicant concluded that they are not likely to exist or, if they do exist, they have a very low probability of activity. In RAI 2.5.1-2, the staff asked the applicant to describe the aerial reconnaissance and other sources it used to support its conclusions regarding the ECFS-N, which is the closest segment to the ESP site. Consistent with its response, the applicant revised SSAR Section 2.5.1.1.4 to reaffirm this conclusion by demonstrating that other researchers and studies have determined that the ECFS-N is not a potential source of seismic activity. SER Section 2.5.1.3.1 provides a complete description of the applicant's response to RAI 2.5.1-2 and the staff's evaluation of the applicant's response.

SSAR Section 2.5.1.1.4 also describes the Giles County, Virginia, seismic zone, which is located near the border with West Virginia. The Giles County seismic zone is defined by a concentration of small to moderate earthquakes and produced the largest historical earthquake in Virginia. This earthquake, referred to as the Giles County earthquake, had an estimated m_b of 5.8 and occurred in 1897. The applicant stated that the shaking at the ESP site from this earthquake would have been about an intensity level of 5, which signifies ground motion that is felt by nearly everyone in the vicinity of the ESP site and might crack plaster or overturn unstable objects. The applicant stated that geologists have not identified any capable tectonic sources in the area that can be associated with the concentration of seismic activity within the Giles County seismic zone. Geologists have identified a zone of small Quaternary-age surface faults within the Giles County seismic zone, near Pembroke, Virginia. However, the applicant stated that these faults do not appear to be related to the seismicity within the Giles County seismic zone, which occurs at depths between 3 and 16 miles beneath the Appalachian basal decollement in the North American basement. The EPRI seismic source model maximum magnitudes (M_{max}) for the Giles County seismic source zone vary from m_b 6.6 to 7.2.

Subsequent hazard studies have used similar values for the M_{max} of the Giles County seismic zone. Therefore, the applicant decided not to revise the EPRI seismic source model for the Giles County seismic zone.

In addition to the principal tectonic features and seismic zones within the ESP site region, the applicant, in SSAR Section 2.5.1.1.4, also described the major active seisomogenic source zones located outside the site region. These sources include the Eastern Tennessee seismic zone (ETSZ), the Charleston seismic source, and the New Madrid seismic zone (NMSZ). These three seismic source zones are more than 300 miles from the ESP site. However, large earthquakes from sources at this distance could contribute to the long-period ground motion hazard at the ESP site. Figure 2.5.1-4, reproduced from SSAR Figure 2.5-14, illustrates these three seismic source zones, as well as other regional seismic source zones.

Eastern Tennessee Seismic Zone

The ESP site is located over 300 miles east of the ETSZ. The ETSZ is about 185 miles long and 30 miles wide and is located in the Valley and Ridge Province of eastern Tennessee. Although the ETSZ has not produced a damaging earthquake in historical time, this zone did produce the second highest release of seismic strain energy in the CEUS during the 1980s. Earthquakes in the ETSZ occur at depths between 3 and 16 miles, and none have exceeded an M_w of 4.6 (Ref. 88, SSAR Section 2.5). In addition, earthquakes within the ETSZ have not been attributed to known faults, and no capable tectonic faults have been identified within the seismic zone. The EPRI seismic source model includes various source geometries and parameters to represent the seismicity of the ETSZ. The M_{max} values used by EPRI for the ETSZ range from m_b 6.6 to 7.4. Subsequent hazard studies have used M_{max} values of m_b 6.45 and 7.25 (Refs. 57 and 79, SSAR Section 2.5). The applicant concluded that both of these more recent estimates of M_{max} are similar to those used by EPRI for the ETSZ. Therefore, the applicant decided not to revise the EPRI seismic source model for the ETSZ.

Charleston Seismic Source

The Charleston seismic source is located about 375 miles south of the ESP site. The earthquake which occurred in Charleston, South Carolina, on August 31, 1886, is the largest historical earthquake event to occur in the eastern United States. The earthquake produced intense shaking in the epicentral area (Modified Mercalli Intensity (MMI) X) and was felt as far away as Chicago (MMI V) (Ref. 90, SSAR Section 2.5). Estimates of the magnitude for the 1886 Charleston earthquake are 7.3 (Ref. 90, SSAR Section 2.5) and 6.8 (Ref. 93, SSAR Section 2.5). The applicant stated that both of these more recent estimates of the magnitude of the Charleston earthquake are similar to the upper bound range of M_{max} values used in the 1986 EPRI study (m_b 6.8 to 7.5). Therefore, the applicant concluded that no new information has been developed since 1986 that would warrant a significant revision to the EPRI seismic source model in terms of earthquake magnitude. However, estimates of earthquake recurrence for the Charleston source, based on dates of paleoliquefaction events, have been updated since 1986. The most recent summary of paleoliquefaction data (Ref. 91, SSAR Section 2.5) for the Charleston source indicates a mean recurrence time of 550 years. This mean recurrence time is roughly an order of magnitude less than the seismicity-based

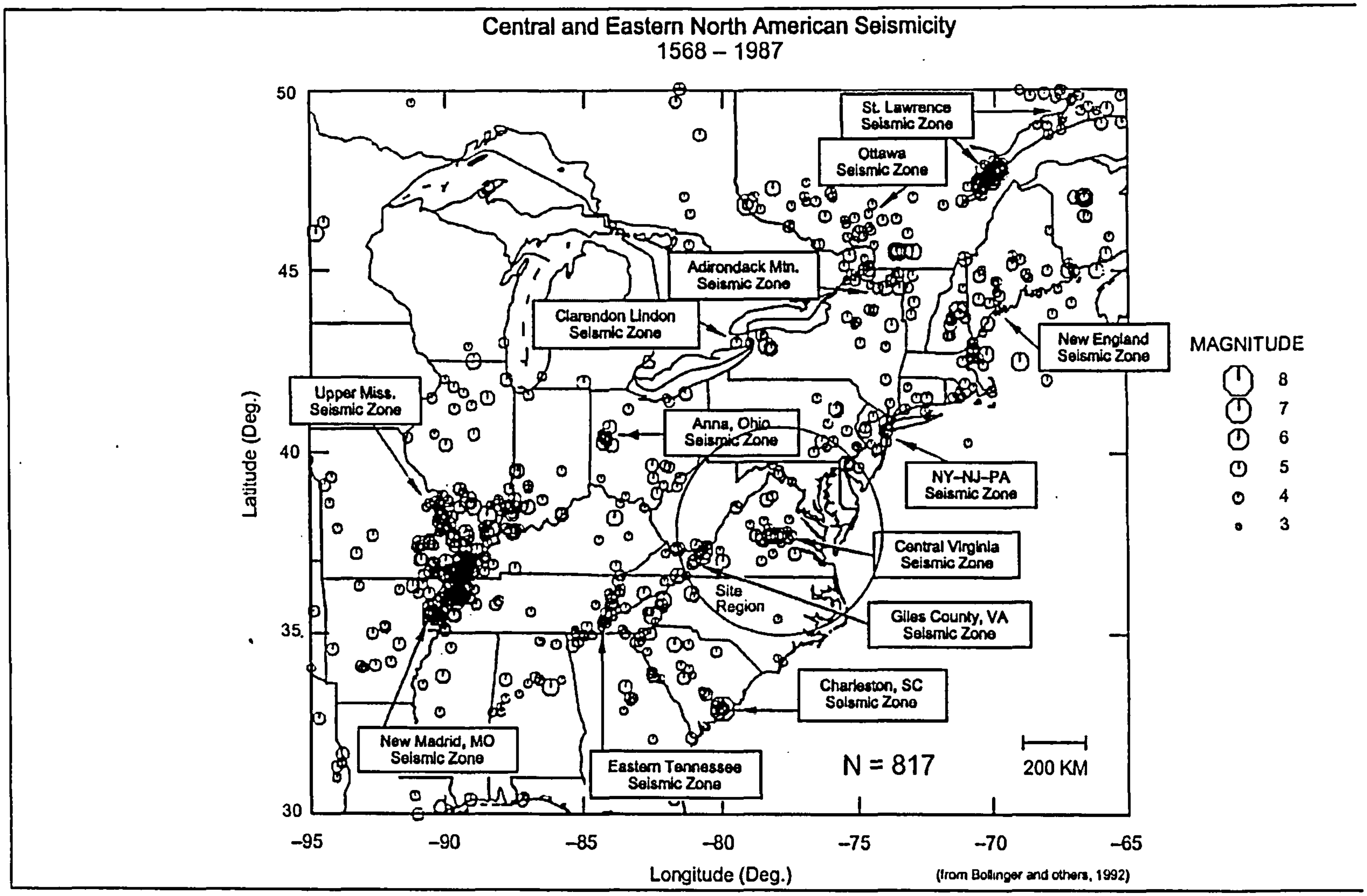


Figure 2.5.1-4 Seismic source zones and seismicity in central and eastern North America

recurrence estimates used in the 1986 EPRI study. Therefore, the applicant modified the Charleston recurrence interval from several thousand years to 550 years, based on the paleoseismic observations. The applicant included this reduction in recurrence interval in its sensitivity analysis, which is described in SSAR Section 2.5.2.

New Madrid Seismic Zone

The NMSZ extends from northeastern Arkansas to southwestern Tennessee and is over 620 miles west of the ESP site. The NMSZ produced three large-magnitude earthquakes between December 1811 and February 1812. Estimates of the magnitudes of these events range between 7 and 8. However, because of the considerable distance between the NMSZ and the ESP site, the NMSZ only contributed 1 percent of the hazard at the NAPS site in the 1986 EPRI study. Since 1986, estimates of the M_{max} for the NMSZ have generally been within the range of M_{max} values used by the EPRI study (m_b 7.2 to 7.9). However, the recurrence interval for the NMSZ, based on paleoseismic observations, is now only 500 years, which is considerably less than the recurrence estimates used in the 1986 EPRI study. The applicant included this reduction in recurrence interval in its sensitivity analysis, which is described in SSAR Section 2.5.2.

Regional Gravity and Magnetic Data

The applicant reviewed regional maps of gravity and magnetic data in SSAR Section 2.5.1.1.5. The Geological Society of America (GSA) published regional maps of gravity and magnetic fields in North America in 1987. The maps present gravity and magnetic field data at a 1:5,000,000 scale. The applicant stated that these maps are useful for identifying and assessing gravity and magnetic anomalies with wavelengths on the order of tens of kilometers or greater.

The gravity map of the eastern United States shows that, at the latitude of Virginia, there is a long-wavelength, east-to-west gravity gradient, referred to as the Piedmont gravity gradient. The Piedmont gravity gradient stretches across the Blue Ridge and Piedmont provinces of Virginia. The applicant stated the following about the Piedmont gravity gradient:

> The presence of the Piedmont Gravity Anomaly was known at the time of the 1986 EPRI study. This anomaly is a first-order feature of the gravity field and is interpreted to reflect eastward thinning of the North American crust and lithosphere.

Magnetic data published by GSA reveal numerous northeast-southwest-trending magnetic anomalies, generally parallel to the structural features of the Appalachian orogenic belt. However, in contrast to the gravity data, the magnetic anomalies do not provide information on crustal-scale features in the lithosphere. Rather, the applicant stated that anomalies in the magnetic field are associated primarily with upper crustal variations in magnetic susceptibility, such as mafic and ultramafic rocks. The magnetic data provide additional characterization of the geophysical properties of the upper crust and supporting evidence for the interpretation of the seismic reflection data. The applicant stated that the magnetic data published since 1986 do not reveal any new anomalies related to geologic structures that had not been identified before the 1986 EPRI study.

2.5.1.1.2 Site Geology

SSAR Section 2.5.1.2 describes the site area in terms of (1) physiography, (2) geologic history, (3) stratigraphy, (4) geologic structure, (5) geologic hazard evaluation, (6) engineering geology, and (7) ground water conditions.

Site Area Physiography

The ESP site is located within the Piedmont province and is bordered by Lake Anna to the north and east. The ESP site is in an area with a topography that is gently undulating, varying in elevation from about 200 to 500 ft. The applicant stated that the slopes in the region typically range from 2 to 5 percent, with steeper slopes along the lower tributaries of some of the larger streams ranging from 7 to 10 percent. Site grade for the existing units is at an approximate elevation of 271 ft. The ground surface gently rises to the west and south to elevations of over 300 ft. Figure 2.5.1-5, reproduced from SSAR Figure 2.5-16, presents the site topographic map.

Site Area Geologic History

The applicant stated that, since early Paleozoic time (about 500 Ma), rocks of the Piedmont province have undergone three compressional orogenies during the Paleozoic Era and one extensional episode during the Mesozoic Era (63–240 Ma). These orogenies produced a complex pattern of folding and faulting in the region surrounding the site. The rocks of the Piedmont province exhibit varying degrees of metamorphism, depending on their location in relation to the axis of major stress, which generally trends northeast-southwest. During the more recent Cenozoic time (63 Ma–present), the area surrounding the ESP site was subject to erosion along the passive continental margin. Erosion continued during the Pleistocene (0.01–2 Ma) glacial and interglacial periods. Weathering processes during the glacial and interglacial periods include frost shattering, freeze-thaw cycles, accelerated wind erosion, and accelerated solifluction (flowage of saturated soil). The applicant concluded that these weathering processes, together with downcutting streams and rivers during the present, produced the residual soils that cover the ESP site.

Site Area Stratigraphy

The applicant stated that the ESP site is underlain by rocks of the Ta River Metamorphic Suite, which are in turn underlain by rocks of the Chopawamsic Formation and the Mine Run Complex. Surficial sediments at the site consist of mainly residual soil and saprolite, with some alluvium found along stream channels. The Ta River Metamorphic Suite underlying the site is thousands of feet thick, and the rocks within the suite are dark gray to black gneisses of Cambrian and/or Ordovician age. The applicant stated that borings completed at the ESP site encountered rocks of the Ta River Metamorphic Suite that are gray to dark gray quartz gneiss and hornblende gneiss. Residual soil and saprolite overlie the rocks of the Ta River Metamorphic Suite. The residual soil is derived from the weathering of the underlying metamorphic rocks and generally consists of clay, silt, and sand-sized particles with minor rock fragments. The saprolite is also derived from weathering of the underlying metamorphic rock but, unlike the residual soil, retains many of the structural and mineralogical features of the rock. The saprolite extends down to the top of the rock from which it was derived.

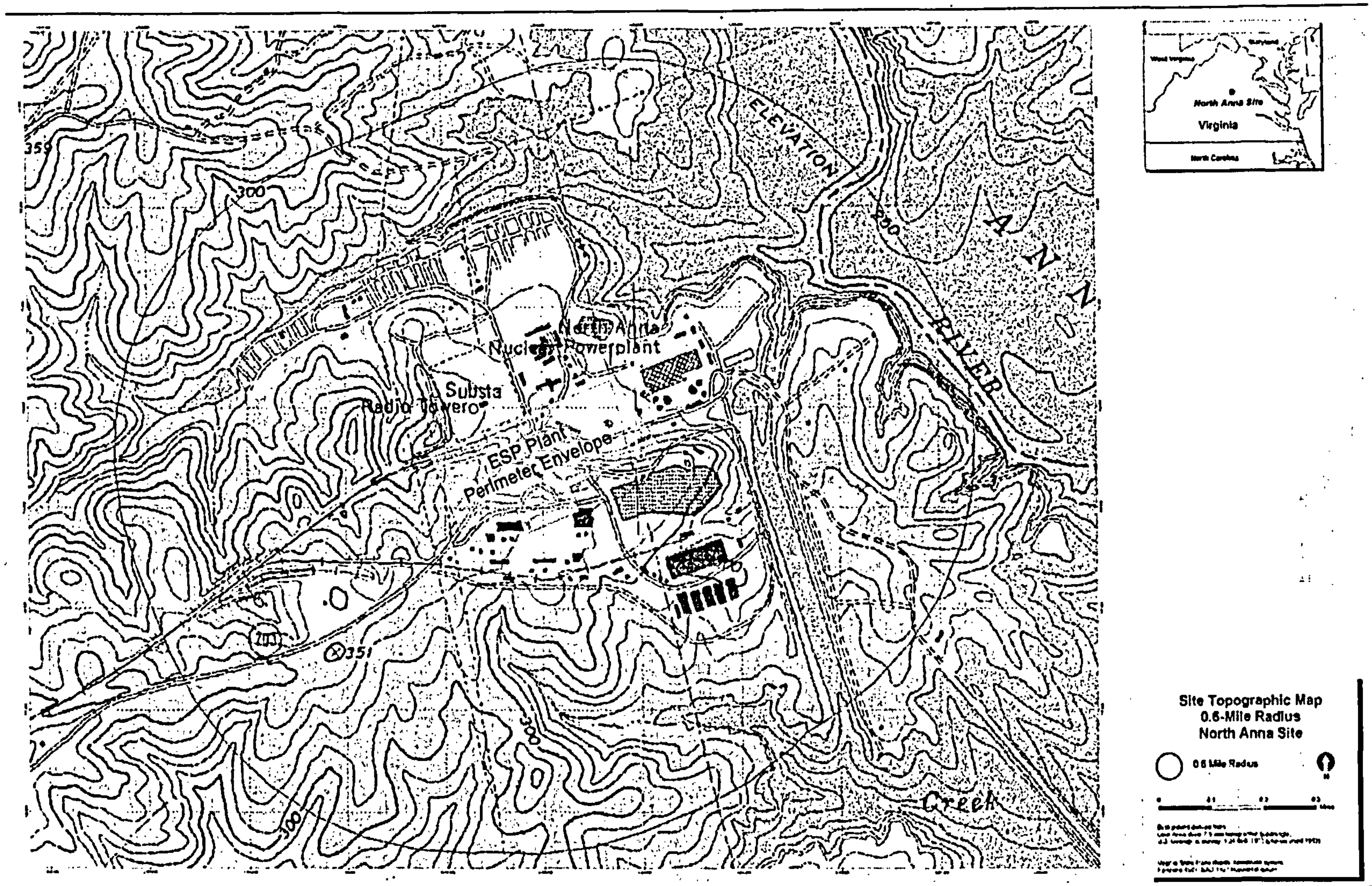


Figure 2.5.1-5 Site topographic map (0.6-mile radius)

Site Area Structural Geology

Structural features at and within a 5-mile radius of the ESP site consist of a series of northeast-striking faults and folds within the metamorphic bedrock. The applicant identified the following bedrock faults within a 5-mile radius of the ESP site:

(1) Spotsylvania thrust
(2) Chopawamsic thrust
(3) Long Branch thrust
(4) Sturgeon Creek fault
(5) unnamed faults "a," "b," and "c"

The applicant stated that none of the above faults are considered to be capable tectonic sources, as defined by RG 1.165. The Spotsylvania, Chopawamsic, and Long Branch thrust faults are northeast-striking, east-dipping Paleozoic structures that can be mapped for miles within the Piedmont province and represent the largest surficial tectonic structures within the site area. The Sturgeon Creek fault and the three unnamed faults ("a," "b," and "c") also strike northeast; however, they are smaller structures than the other three thrust faults. Unnamed fault "a," which traverses NAPS and the ESP site, was the subject of intensive study following its exposure during the excavations for abandoned Units 3 and 4. This fault has a length of about 3000 ft based on geologic mapping of excavations and trenches. The applicant cited the conclusions of a Dames and Moore study (Ref. 9, SSAR Section 2.5), stating that unnamed fault "a" is not a capable tectonic source, as well as the NRC staff's acceptance of this conclusion found in the SER for abandoned NAPS Units 3 and 4.

The applicant stated that the most prominent folds at the site are the northerly plunging syncline/anticline pair located in the western portion of the site. The axis of the site passes near an area of exposed bedrock, and foliations near the axis of the fold dip steeply (65–90 degrees).

Site Area Geologic Hazard Evaluation

SSAR Section 2.5.1.2.5 states that the only geologic hazards associated with the ESP site are (1) vibratory ground motion from regional earthquake activity and (2) potential surface faulting from site area earthquakes. The applicant discussed these two potential geologic hazards in SSAR Sections 2.5.2 and 2.5.3, respectively. The corresponding sections of this SER provide the staff's review of these two potential geologic hazards.

Site Engineering Geology

SSAR Section 2.5.1.2.6 briefly describes the engineering behavior of the soil and rock at the ESP site, prior earthquake effects, effects of human activities, construction ground water control, and unforseen geologic features. Section 2.5.4 of the SSAR discusses the results of the applicant's geotechnical investigation in greater detail.

The applicant described the composition of the saprolite at the ESP site as micaceous silty, clayey sand and sandy silt/clay with occasional to many relict rock fragments. The saprolite more or less retains the fabric or structure of the parent bedrock, depending on the degree of weathering. However, although the saprolite has the relict structure of the parent bedrock, its engineering properties typically resemble those of a soil. The applicant classified the saprolite at the site into Zone IIA and IIB saprolite, based on its general composition and grain size. Zone IIA saprolite is classified as silty sand, clayey sand, and high- and low-plasticity silt and clay. Zone IIB saprolite is classified as silty sand. Zone IIA saprolite is the more weathered of the two saprolites and contains less than 10 percent relict rock fragments. In contrast, Zone IIB saprolite contains between 10 and 50 percent relict rock fragments and is more dense than Zone IIA saprolite. The presence of mica in the saprolite is likely to reduce its maximum compacted density and increase its compressibility. The applicant provided the following example of this phenomenon:

> The SWR [service water reservoir] pump house for the existing units was constructed on about 65 feet of Zone IIA saprolite, consisting mainly of sandy silt, with frequent layers of micaceous sandy silt. For about two years after its construction, the pumphouse structure underwent relatively high settlement that declined significantly thereafter. The settlement was caused by the weight of the SWR dike fill built up around the pumphouse. The micaceous nature of the material is considered to have played a major role in the settlement. High compressibilities and low maximum densities of the saprolite, therefore, preclude using it as engineered fill at the ESP site.

The applicant stated that bedrock at the ESP site is composed of predominantly quartz gneiss with biotite of the Ta River Metamorphic Suite. The gneiss is a hard, foliated rock, which exhibits various degrees of weathering. The degree of weathering of the gneiss affects its engineering behavior and properties. The applicant classified the gneiss at the site into three categories (Zones III, III-IV, and IV) based on its degree of weathering. Zone III is the uppermost weathered part of the bedrock, is highly weathered and fractured, and contains traces of clay and iron oxide. Regarding Zone III, the applicant stated the following:

> Because of the tendency for zones of severely weathered and fractured rock to weather further upon exposure, they would be removed and replaced with cement grout where encountered in excavations for the new units. This would ensure the bearing capacity of the foundation rock mass.

Zones III-IV and IV are considerably less weathered, with the degree of weathering decreasing with increasing depth. Zone III-IV is moderately weathered, and Zone IV is slightly weathered to fresh. Based on the testing of rock borings, the applicant concluded that Zones III-IV and IV are suitable bearing surfaces for Category I plant structures. The applicant did not consider the joints and fractures present in both zones to be of sufficient density or extent to affect the engineering behavior of the rock with respect to its bearing capacity or integrity.

The applicant stated that no physical evidence of any fissuring, liquefaction, landsliding, lurching, or caving of banks exists to indicate that past earthquake ground shaking has disturbed either the surficial sediments or the bedrock beneath the ESP site. This result follows from the relatively low intensity of historic ground shaking at the site.

The major potential effect of human activity on the ESP site is the mining in the vicinity of the site which occurred from the 1700s to 1974. Sulfide and gold deposits have been mined predominantly in and around the town of Mineral, Virginia, approximately 7 miles west of the site. The closest mining deposit, the Allah Cooper deposit, is about 3 miles northwest of the site. The applicant stated that, based on published documentation of these mining activities and their distance from the site, the activities have not affected, nor would they affect, the ESP site.

The applicant stated that ground water withdrawal from the surficial sediments and bedrock around the ESP site is not an issue because of the low withdrawal quantities and the limited areal extent of the withdrawals. Current site ground water withdrawal is generally limited to water supply wells for plant drinking and process water purposes.

Concerning construction ground water control issues, the applicant stated that ground water at the ESP site generally occurs at depths ranging from about 6 to 58 ft below the present day ground surface. The exception to this is the excavation area of the abandoned Units 3 and 4, which was partially backfilled and where ground water is within about 2 ft of the ground surface. The applicant further stated that ground water levels at the site would likely result in the need for temporary dewatering of foundation excavations extending below the water table.

Concerning the potential for unforseen geologic features, the applicant stated that it would (1) geologically map future excavations for safety-related structures and (2) evaluate any unforseen geologic features that are encountered. In addition, the applicant stated that it would notify the NRC "when any excavations for safety-related structures are open for their examination and evaluation."

Site Ground Water Conditions

The applicant stated that ground water at the ESP site is present in unconfined conditions in both the surficial sediments and underlying bedrock. Ground water movement at the site is generally to the north and east, toward Lake Anna. Hydraulic conductivity values for the saprolite range from about 0.2 to 3.4 ft/d. SSAR Section 2.4.12 provides a detailed description of the site ground water conditions.

2.5.1.2 Regulatory Evaluation

SSAR Section 2.5.1 presents information on the geologic and seismologic characteristics of the ESP site region and area. In SSAR Section 1.8, the applicant stated that the information presented in SSAR Section 2.5.1 conforms to the requirements of GDC 2 in Appendix A to 10 CFR Part 50, Subpart A of 10 CFR Part 52, and 10 CFR Part 100. The applicant also stated in this section that it developed the geologic and seismologic information in accordance with the guidance presented in RGs 1.70, 1.165, 4.7 (Revision 2 dated 1998), 1.132, "Site Investigations for Foundations of Nuclear Power Plants," Revision 2, dated October 2003, and RS-002. The staff reviewed this portion of the application for conformance with the applicable regulations, and considered the corresponding regulatory guidance, as identified above with the exception that an ESP applicant need not demonstrate compliance with the GDC.

In reviewing the SSAR, the staff considered the regulations at 10 CFR 52.17(a)(1)(vi) and 10 CFR 100.23(c), which require that the applicant for an ESP describe the seismic and geologic characteristics of the proposed site. In particular, 10 CFR 100.23(c) requires that an ESP applicant investigate the geologic, seismologic, and engineering characteristics of the proposed site and its environs with sufficient scope and detail to support evaluations to estimate the SSE ground motion and to permit adequate engineering solutions to actual or potential geologic and seismic effects at the site. Section 2.5.1 of NUREG-0800, RG 1.165, and Section 2.5 of RG 1.70 provide specific guidance concerning the evaluation of information characterizing the geology and seismology of a proposed site.

2.5.1.3 Technical Evaluation

This section of the SER provides the staff's evaluation of the geologic and seismologic information submitted by the applicant in SSAR Section 2.5.1. The technical information presented in SSAR Section 2.5.1 resulted from the applicant's surface and subsurface geological, seismological, and geotechnical investigations performed in progressively greater detail as they moved closer to the site. Through its review, the staff determined whether the applicant complied with the applicable regulations and conducted its investigations with an appropriate level of thoroughness within the four areas designated in RG 1.165, which are based on various distances from the site (i.e., 200 miles, 25 miles, 5 miles, and 0.6 mile).

SSAR Section 2.5.1 contains the geologic and seismic information gathered by the applicant in support of the vibratory ground motion analysis and site SSE spectrum provided in SSAR Section 2.5.2. According to RG 1.165, applicants may develop the vibratory design ground motion for a new nuclear power plant using either the EPRI or LLNL seismic source models for the CEUS. However, RG 1.165 recommends that applicants update the geological, seismological, and geophysical database and evaluate any new data to determine whether revisions to the EPRI or LLNL seismic source models are necessary. As a result, the staff focused its review on geologic and seismic data published since the late 1980s that could indicate a need for changes to the EPRI or LLNL seismic source models.

To thoroughly evaluate the geologic and seismologic information presented by the applicant, the staff obtained the assistance of USGS. The staff and its USGS advisors visited the ESP site and surrounding area to confirm the interpretations, assumptions, and conclusions presented by the applicant concerning potential geologic and seismic hazards. The staff's review of SSAR Section 2.5.1 focused on (1) tectonic or seismic information, (2) nontectonic deformation information, and (3) conditions caused by human activities, with respect to both the regional and site geology.

2.5.1.3.1 Regional Geology

The staff focused its review of SSAR Section 2.5.1.1 on the applicant's description of the regional tectonics, with emphasis on the Quaternary Period, structural geology, seismology, paleoseismology, physiography, geomorphology, stratigraphy, and geologic history within a distance of 200 miles from the site. Based on its review of SSAR Sections 2.5.1.1.1, 2.5.1.1.2, and 2.5.1.1.3, as described below, the staff concludes that the applicant provided a thorough and accurate description of these geologic features and characteristics in support of the ESP application. In SSAR Section 2.5.1.1.1, the applicant described each of the physiographic provinces within the site region, with an emphasis on the Piedmont province, where the ESP site is located. In SSAR Section 2.5.1.1.2, the applicant described the geologic history of the ESP site region, including each of the episodes of continental collisions and rifting. In SSAR Section 2.5.1.1.3, the applicant described the regional stratigraphy of the Piedmont province, including the major rock units underlying the site. These three SSAR sections describe well-documented geologic information, and the staff concludes that they contain an accurate and thorough description of the regional geology as required by 10 CFR 52.17 and 10 CFR 100.23.

In SSAR Section 2.5.1.1.4, the applicant described the principal tectonic structures within the 200-mile ESP site region based on the age of formation or reactivation of the structures. To define the Quaternary tectonic (2 Ma–present) features, the applicant used the study of Crone and Wheeler (Ref. 59, SSAR Section 2.5) as one of its criteria. This study is a compilation of geologic information on Quaternary faults, liquefaction features, and possible tectonic features in the CEUS. Crone and Wheeler evaluated and classified these features into one of four categories (Classes A, B, C, and D) based on geologic evidence of Quaternary faulting or deformation. The Crone and Wheeler classifications are based on an evaluation of the information that is available in the published geoscience literature and not on a direct examination of the actual geologic features. The applicant used the Crone and Wheeler classifications as one of its criteria (SER Section 2.5.1.1.1 describes other criteria used by the applicant) for assessing the potential Quaternary activity of the following faults:

- Hylas shear zone
- Lake of the Woods thrust fault
- Mesozoic rift basins
- Stafford fault system
- Central Virginia seismic zone
- Mountain Run fault zone
- seven fall lines
- East Coast fault system

For some of the above faults, the applicant used the Crone and Wheeler classifications as its primary basis for assessing the potential Quaternary activity.

The staff determined that the applicant's use of the Crone and Wheeler classifications as a sole or primary basis for assessing the potential Quaternary activity of the above features was insufficient. Therefore, the staff asked the applicant in RAIs 2.5.1-1 through 2.5.1-6 to provide additional information to substantiate its claims for categorizing these features as noncapable. The following sections describe the applicant's responses to RAIs 2.5.1-1 through 2.5.1-6 and the staff's evaluation of these responses.

Central Virginia Seismic Zone

Concerning the Quaternary tectonic features within the ESP site region, the applicant concluded that only the CVSZ shows geologic evidence that demonstrates the existence of a Quaternary fault of tectonic origin. The ESP site is located near the northern boundary of the CVSZ (see SER Figures 2.5.1-3 and 2.5.1-4). The CVSZ is an area defined by moderate to low historical seismic activity, as well as paleoseismicity, since Obermeier and McNulty recently identified two paleoliquefaction features within the CVSZ (Ref. 71, SSAR Section 2.5). In its response to RAI 2.5.1-1, the applicant stated that it interpreted the liquefaction features identified by Obermeier and McNulty to represent at least one, and possibly two, moderate magnitude earthquakes in the CVSZ in the middle to late Holocene epoch. However, because of the absence of liquefaction features in otherwise susceptible middle to late Holocene deposits elsewhere in the study area, Obermeier interprets these liquefaction features as the result of localized, moderately sized (magnitude approximately 5.5 to 6.5) earthquakes. The applicant stated that larger earthquakes with a magnitude of approximately 7 would have produced a more widespread liquefaction field with more numerous, larger liquefaction features. As a basis for its conclusion, the applicant stated that Dr. Obermeier canvassed thousands of meters of exposure of liquefiable deposits in his search area, and the absence of liquefaction in these deposits and the restricted nature of the observed liquefaction features indicate that a magnitude 7 earthquake has not occurred in the Holocene and that abundant magnitude 6 to 7 earthquakes have not occurred in the Holocene within the CVSZ.

Concerning the implications of possibly two moderate-sized (magnitude 5.5 to 6.5) earthquakes occurring in the CVSZ during the middle to late Holocene epoch (past 5,000 to 10,000 years), the applicant stated that the occurrence of these earthquakes is consistent with the EPRI seismic source recurrence estimates for the CVSZ. The average recurrence interval for earthquakes with a magnitude greater than 6 within the CVSZ in the EPRI source model is 7055 years. For somewhat smaller events (magnitude greater than 5.5), the EPRI source model estimates about six events over a period of 10,000 years.

Because of the absence of widespread liquefaction features in susceptible Holocene soil deposits surveyed by geologists, the staff concurs with the applicant's conclusion that the few liquefaction features within the CVSZ are most likely caused by a few local moderate-magnitude earthquakes. The staff concludes that the applicant accurately characterized the impact of the paleoliquefaction features on the overall seismic characterization of the CVSZ. In addition, the staff concurs with the applicant's conclusion that the occurrence of these earthquakes is consistent with the EPRI seismic source recurrence estimates for the CVSZ. Section 2.5.1.1.1 of this SER summarizes the applicant's revisions to SSAR Section 2.5.1 as a result of RAI 2.5.1-1.

East Coast Fault System

The applicant cited another potential Quaternary tectonic feature known as the ECFS. The ECFS-N is located approximately 70 miles southeast of the ESP site. Figure 2.5.1-6, reproduced from the applicant's response to RAI 2.5.1-2, shows the postulated ECFS-S, ECFS-C, and ECFS-N. The applicant concluded, in SSAR Section 2.5.1.1.4, that the ECFS-N "probably does not exist or has a very low probability of activity if it does exist." The applicant based its conclusion, in part, on an aerial reconnaissance of the ECFS-N. In its response to RAI 2.5.1-2, the applicant stated that it primarily relied on a review of the evidence presented by Marple and Talwani (Ref. 74, SSAR Section 2.5) to conclude that the ECFS-N probably does not exist or, if it does exist, it has a very low probability of being active during the late Cenozoic Era. Specifically, the applicant stated that, "In our view, Marple and Talwani did not perform a very detailed or rigorous geomorphic analysis to conclude that an active fault is present beneath the coastal plain of North Carolina and Virginia." The applicant stated that its aerial reconnaissance of the ECFS-N played an important, but less significant, role in developing this conclusion.

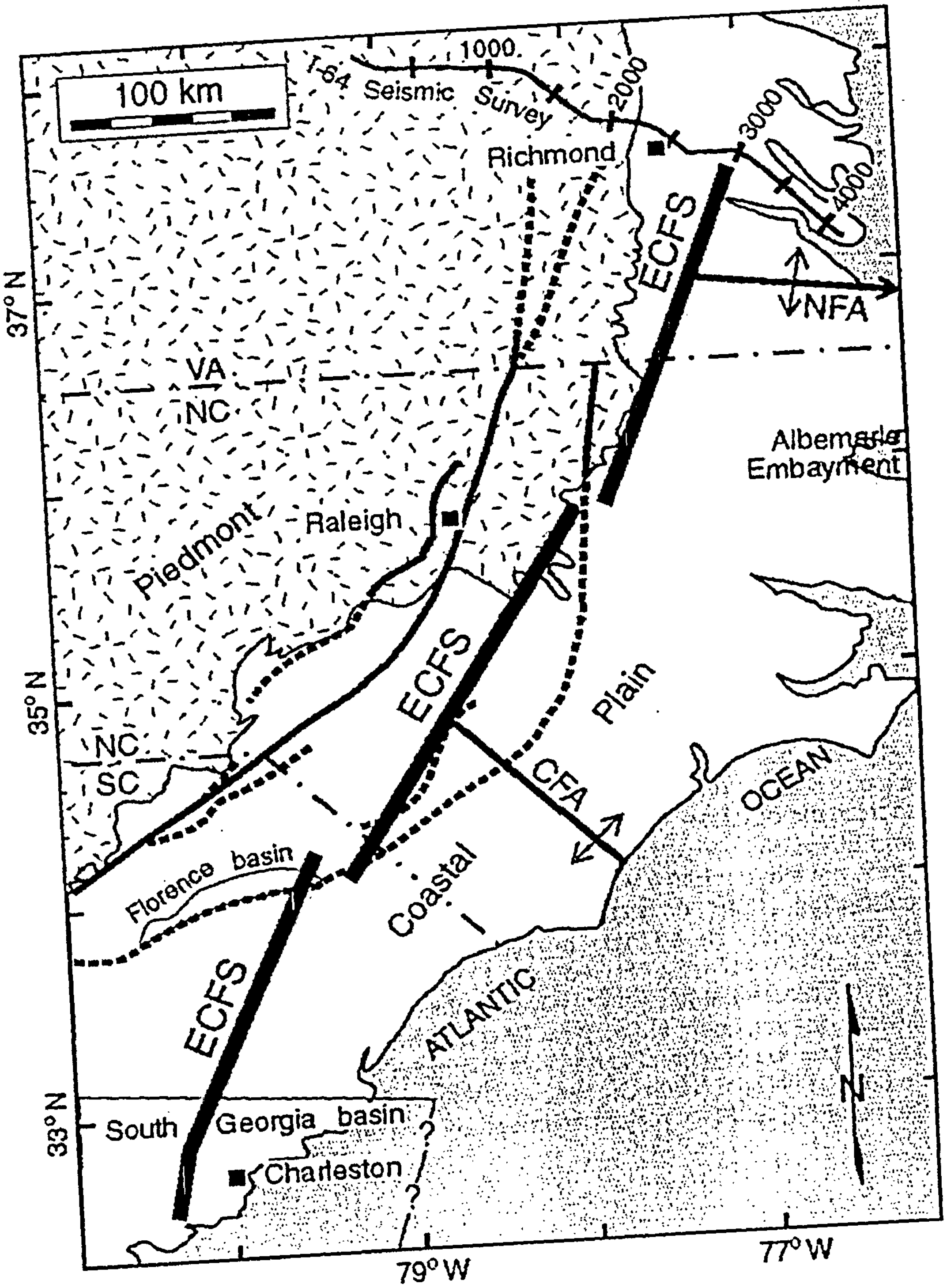


Figure 2.5.1-6 Map showing general area of coverage of Obermeier and McNulty (1998) liquefaction study relative to interpretations of the Central Virginia Seismic Zone.

To support its conclusion regarding the ECFS-N, the applicant evaluated the (1) geological data, (2) geophysical and seismological data, and (3) geomorphic data used by Marple and Talwani to infer the presence of the ECFS-N. The applicant stated that the only geologic data that Marple and Talwani cite in support of the ECFS-N is the coincidence of the ECFS-N with the westward termination of the Norfolk arch axis, which is shown above in Figure 2.5.1-6. In their paper, Marple and Talwani note that their depiction of the Norfolk arch axis is modified from a small-scale map in Pazzaglia (Ref. 6, RAI 2.5.1-2 in RAI Letter No. 3), which shows the Norfolk arch axis terminating westward against the Fall Line. The Fall Line is the boundary between the Coastal Plain and Piedmont physiographic provinces and is a narrow zone of small waterfalls and rapids that occurs at the point where the major rivers pass from the resistant granites and other ancient rocks of the Piedmont to the more easily eroded sands, clays, and shales of the Coastal Plain. Low hills rise to elevations of about 300 ft along the Fall Line. Regarding this modification by Marple and Talwani, the applicant stated the following:

> Specifically, Marple and Talwani (2000) have modified Pazzaglia's map by showing the Norfolk arch axis as terminating about 25 km east of the Fall Zone, on trend with their inferred location of the ZRA-N [ECFS-N]. Marple and Talwani (2000) provide no additional references, interpretations or original data to justify their changes to Pazzaglia's map of the Norfolk arch axis. Thus, it is not possible to determine if their modification of the Norfolk arch axis is based on independent data, or simply a re-interpretation of the Norfolk arch location that is compatible with their model of the ZRA-N [ECFS-N]. We conclude that the location of the Norfolk arch axis, as presented in Marple and Talwani (2000), does not provide independent geologic evidence in support of the ZRA-N [ECFS-N]. Therefore, there is no known geologic evidence to support the existence of the ZRA-N [ECFS-N].

The geophysical or seismological data presented by Marple and Talwani in support of the ECFS-N is an east-west trending seismic reflection profile along Interstate 64 (I-64) through Central Virginia. This geophysical inference of the ECFS-N is based on the Marple and Talwani characterization of the seismic reflection data presented in a publication by Pratt et al. (Ref. 7, RAI 2.5.1-2 in RAI Letter No. 3). However, the applicant pointed out that Pratt and others do not interpret a steeply dipping crustal shear zone in the vicinity of the ECFS-N. The only crustal-scale structure in this region interpreted by Pratt and others is an east-dipping shear zone that underlies the Goochland terrain about 30 km beneath the inferred location of the ECFS-N. As such, the applicant concluded that the I-64 seismic reflection profile does not support the interpretation by Marple and Talwani.

The geomorphic data that Marple and Talwani use to postulate the existence of the ECFS-N are inferred river anomalies. Specifically, Marple and Talwani use their interpretation of geomorphic anomalies along streams that cross the inferred location of the ECFS-N to postulate its existence. These anomalies include channel incision, upward-displaced fluvial surfaces, cross-valley change, sinuosity change, anastomosing stream pattern, and stream deflections. The applicant stated that of these six categories of river anomalies, only "upward-displaced fluvial surfaces" require a tectonic interpretation. The other five anomalies are examples of channel pattern change that can be and typically are produced by non-tectonic processes. The applicant examined each of these river anomaly categories with reference to the ECFS-N to weigh the evidence for its existence and concluded the following:

> Based on our independent assessment of "river anomalies" on the ZRA-N [ECFS-N], we find (1) no evidence for the existence of a fault and (2) direct stratigraphic evidence against the types of deformation postulated by Marple and Talwani (2000). In some cases, we could not verify or duplicate geomorphic observations, such as channel incision, cited by Marple and Talwani (2000). The "upward displaced fluvial surfaces" cited in their paper are inferred only from qualitative analysis of convexities of river profiles and, therefore, this type of "anomaly" does not provide evidence for tectonic uplift and is inconsistent with other geomorphic observations. And finally, we documented direct stratigraphic evidence for no Quaternary deformation in the vicinity of a large meander of the Nottoway River that Marple and Talwani (2000) interpreted to have formed in response to systematic folding and northeastward tilting. We conclude that the fluvial geomorphic features cited by Marple and Talwani (2000) are likely produced by non-tectonic fluvial processes, are not anomalous, and, thus do not support their interpretation of the presence and activity of the ZRA-N (northern segment of the ECFS).

To evaluate the applicant's response to RAI 2.5.1-2, the staff reviewed the evidence presented by Marple and Talwani as well as the applicant's analyses of the evidence to support the existence of the ECFS-N. The staff finds that the geologic, seismologic, and geomorphic evidence presented by Marple and Talwani to support the existence of the ECFS-N is questionable. The staff concurs with the applicant's conclusion that the majority of the geologic data cited by Marple and Talwani in support of their postulated ECFS apply only to the central and southern segments. There are no Cenozoic faults or structure contour maps indicating uplift along the ECFS-N. Accordingly, the staff finds that evidence for the existence and recent activity of the northern segment of the ECFS is low; however, the staff believes that the ECFS-N should be included as a possible contributor to the seismic hazard for the ESP site. The applicant gave the ECFS-N a 10 percent probability of existence as part of its modeling of the seismic sources to determine the SSE. The staff believes, based on its review of the evidence, that a 10 percent probability of existence is an acceptable value. In summary, the staff concludes that the applicant has adequately investigated the possibility of the existence of an ECFS-N. Section 2.5.1.1.1 of this SER summarizes the applicant's revisions to SSAR Section 2.5.1 resulting from RAI 2.5.1-2.

<u>Local Faults</u>

Other potential Quaternary tectonic features characterized by the applicant include the Hylas shear zone, Mountain Run fault zone, and Lake of the Woods thrust fault. The Hylas shear zone, Mountain Run fault zone, and Lake of the Woods thrust fault are prominent structural features between 5 and 25 miles from the ESP site (see SER Figure 2.5.1-2). The applicant concluded that these Paleozoic faults have not been reactivated and are therefore not capable tectonic sources. In RAI 2.5.1-4, the staff asked the applicant to explain its conclusions regarding the Hylas shear zone and Lake of the Woods thrust fault. In its response to RAI 2.5.1-4, the applicant stated that these faults show no concentration or alignment of historic seismicity, geomorphic expression, or Quaternary deformation. The applicant further stated that, based on its review of the literature, these faults are Paleozoic structures with mylonitic shear textures. This implies that the faults formed at deep crustal levels and that their current surface exposure is the result of exhumation. Based on geologic evidence of Quaternary faulting or deformation, Crone and Wheeler (Ref. 59, SSAR Section 2.5) categorize the

Mountain Run fault zone as only Class C. Crone and Wheeler's comprehensive database of Quaternary features does not mention the Hylas shear zone and Lake of the Woods thrust fault. Based on the lack of historical seismicity, geomorphic evidence, and Quaternary deformation along the Lake of the Woods thrust fault and Hylas shear zone, the staff concurs with the applicant's conclusion that these two faults are Paleozoic faults that have not been reactivated during the Quaternary Period. Section 2.5.1.1.1 of this SER summarizes the applicant's revisions to SSAR Section 2.5.1 resulting from RAI 2.5.1-4.

In RAI 2.5.1-5, the staff asked the applicant to describe the physiographic features associated with the Mountain Run and Kelly's Ford scarps along the Mountain Run fault zone which led the applicant to conclude that the scarps resulted from fluvial erosion and not tectonic deformation. In its response, the applicant stated that it performed reconnaissance-level field and aerial evaluations of the Mountain Run fault zone. To evaluate the potential for Quaternary activity of the Mountain Run fault zone, the applicant examined several geologic profiles across the Mountain Run fault zone, including both the Mountain Run and Kelly's Ford scarps. Based on its examination across these geologic profiles, the applicant concluded the following:

- No consistent expression of a scarp is present along the Mountain Run fault in the vicinity of the Rappahannock River. The northwest-facing Kelly's Ford scarp is similar to a northwest-facing scarp along the southeastern valley margin of Mountain Run; both scarps were formed by streams that preferentially undercut the southeastern valley walls, creating asymmetric valley profiles.

- No northwest-facing scarp is associated with the Mountain Run fault zone between the Rappahannock and Rapidan rivers. Undeformed late Neogene (2–5 Ma) colluvial deposits bury the Mountain Run fault zone in this region, demonstrating the absence of Quaternary (2 Ma–present] fault activity.

- The northwest-facing Mountain Run scarp southwest of the Rapidan River alternates with a southeast-facing scarp on the opposite side of the Mountain Run valley; both sets of scarps have formed by the stream impinging on the edge of the valley.

Based on the evidence cited in the applicant's response, the staff concludes that the scarps along the Mountain Run fault zone are most likely products of fluvial erosion and not Cenozoic fault activity. In particular, the Mountain Run fault zone is overlain by undeformed late Neogene colluvial deposits and thus has not experienced Quaternary surface fault rupture. Section 2.5.1.1.1 of this SER summarizes the applicant's revisions to SSAR Section 2.5.1 resulting from RAI 2.5.1-5.

The applicant also identified the seven fall lines across the Piedmont and Blue Ridge provinces of North Carolina as another potential Quaternary tectonic feature. Weems identified these seven fall lines (Ref. 70, SSAR Section 2.5), which are based on the alignment of short stream segments with anomalously steep gradients. Because other studies of potential tectonic features in the CEUS do not include the seven fall lines identified by Weems, the applicant concluded that they do not represent a capable tectonic source. In its response to RAI 2.5.1-3, the applicant stated that Weems does not present direct credible evidence for a tectonic origin of the fall lines. The applicant stated that the fall lines described by Weems are not defined by formal, consistently applied criteria, and thus are not as well defined and laterally continuous as depicted. In particular, Weems selectively correlated different features to form a laterally continuous fall line, while in other cases similar features are not correlated. The applicant also stated that, based on its evaluation of the stratigraphic, structural, and geomorphic relations across and adjacent to the fall zones, differential erosion resulting from variable bedrock hardness is a more plausible explanation than Quaternary tectonism. As part of its response to RAI 2.5.1-3, the applicant presented a detailed analysis of geologic and geomorphic data to support its conclusion that the fall lines are not tectonic features. This analysis shows that Weems postulated three hypotheses for the origins of the fall lines in the Blue Ridge and Piedmont provinces:

(1) variable erosion across linear belts of rocks of varying hardness

(2) late Cenozoic climatic and sea level fluctuations, producing "waves" of headwater-retreating nick points that are expressed as fall zones and fall lines

(3) localized neotectonic uplift along fall lines

Weems rejected the first two hypotheses, stating that control of fall lines by rock hardness "is true only locally and occurs as a consequence of uplift." He also stated that climatic control does not adequately explain the observed patterns of fall lines. Weems concluded that tectonic uplift "is the dominant cause of the existing Piedmont fall lines" because neither differential rock erosion, nor regional creation of nick points by climate-driven changes in fluvial patterns, could "adequately explain the observed patterns." The applicant concluded that Weems adopted a tectonic interpretation primarily because the alternative interpretations were less compelling, and not because of direct evidence supporting a tectonic origin. The applicant also found that it was unable to reproduce Weems' delineation of individual fall zones or his correlations of fall zones as laterally continuous fall lines. In summary, the applicant found that Weems' model for the lateral continuity of fall lines for hundreds of miles along trend in the Blue Ridge and Piedmont provinces is based on subjective assessments of some steep stream reaches as anomalous fall zones.

To further assess the claims made by Weems, the applicant conducted geomorphic analyses of the Tidewater and Central Piedmont fall lines because these two features lie within the North Anna site vicinity. Concerning the Tidewater fall line, the applicant found that a profile of Pliocene marine sand shows no deformation across the Tidewater fall line at the Rappahannock River. The applicant also found that a very strong correlation exists between variations in rock type and gradient changes in the South Anna River profile that strongly suggests that the Tidewater fall line formed as a result of variable erosion across rocks of varying hardness. Concerning the Central Piedmont fall line, the applicant found that the increased gradients along the Rapidan and Rappahannock Rivers as they exit the Culpeper Basin are associated with Jurassic igneous rocks and Paleozoic metamorphic rocks, not Triassic basin sediments as stated by Weems. The applicant stated that the observed gradient as the streams leave the basin is explained by differential erosion of bedrock without invoking tectonic deformation along the Central Piedmont fall line.

Based on the evidence cited by the applicant in response to this RAI, in particular the applicant's evaluation of the stratigraphy and structural relations associated with the fall zones, the staff concludes that the applicant has accurately characterized the seven fall lines as nontectonic features. The staff concurs with the applicant's interpretation that differential erosion resulting from variable bedrock hardness is a more plausible explanation than

Quaternary tectonism for the fall lines. The staff notes that evidence for the existence of the seven fall lines as a Quaternary tectonic feature is based solely on the work of Weems and that other geologists have not made this inference. Section 2.5.1.1.1 of this SER summarizes the applicant's revisions to SSAR Section 2.5.1 resulting from RAI 2.5.1-3.

The Stafford fault system approaches to within 16.5 miles of the ESP site to the northeast. In SSAR Section 2.5.1.1.4, the applicant concluded that there is no Quaternary activity along the fault system. In RAI 2.5.1-6, the staff asked the applicant to elaborate on the field observations and aerial reconnaissance that support this conclusion. In its response, the applicant stated that it based its conclusion that the Stafford fault system is not a capable tectonic source on a review of existing literature, discussions with researchers familiar with the area, aerial and field reconnaissance, and geomorphic analyses. The applicant examined the topographic profiles of several terraces that cross the Stafford fault system and found only minor, nontectonic relief on some of the terrace surfaces. In addition, the applicant did not find any scarps or anomalous breaks in the topography on the terrace surfaces associated with the mapped fault traces. Based on the evidence cited by the applicant, in particular the applicant's examination of the topography of the profiles that cross the fault system, the staff concludes that the applicant accurately characterized the Stafford fault system as being inactive during the Quaternary Period.

Based on its review of SSAR Section 2.5.1.1.4 and the applicant's responses to the RAIs, cited above, the staff concludes that the applicant identified and properly characterized all regional tectonic features. The staff concludes that SSAR Section 2.5.1.1.4 provides an accurate and thorough description of the regional tectonics, with an emphasis on potential Quaternary activity, as required by 10 CFR 52.17 and 10 CFR 100.23.

To support its geologic interpretations of the region surrounding the ESP site, the applicant in SSAR Section 2.5.1.1.5 reviewed the regional maps of gravity and magnetic anomalies published by GSA in 1987. The applicant used the regional gravity map to identify the Piedmont gravity gradient and interpreted this feature as an eastward thinning of the North American crust and lithosphere. The applicant interpreted the regional magnetic anomalies as upper crustal variations in magnetic susceptibility, such as mafic and ultramafic rocks, and used the magnetic data as supporting evidence for its interpretation of its seismic reflection data. The staff concludes that the regional gravity and magnetic data support the applicant's overall conclusions concerning the regional geologic and tectonic features.

2.5.1.3.2 Site Geology

The staff focused its review of SSAR Section 2.5.1.2 on the applicant's description of the site-related geologic features, seismic conditions, and conditions caused by human activities. Based on its review of SSAR Sections 2.5.1.2.1 and 2.5.1.2.2, described below, the staff concludes that the applicant has provided a thorough and accurate description of these geologic features and characteristics in support of the ESP application. In SSAR Section 2.5.1.2.1, the applicant described the local topography as gently undulating, varying in elevation from about 200 to 500 ft with the site grade for the existing units at about 271 ft. In SSAR Section 2.5.1.2.2, the applicant described the compressional orogenies and extensional episode that produced the folding and faulting in the region surrounding the site. The applicant also described the local erosion and weathering that produced the residual soils that cover the ESP site. The staff concludes that these two SSAR sections, which describe readily observable local geologic features, contain an accurate and thorough description of the local site geology as required by 10 CFR 52.17 and 10 CFR 100.23.

In SSAR Section 2.5.1.2.3 the applicant described the soil and rock layering beneath the ESP site. The applicant based its description of the site stratigraphy on several borings performed for the existing NAPS Units 1 and 2 and the abandoned NAPS Units 3 and 4, and as part of the ESP application subsurface program. The applicant stated in SSAR Section 2.5.1.2.3 that the borings drilled as part of the ESP application subsurface program reveal "severely weathered, fractured and jointed intervals in Zone III-IV and Zone IV rock," and that these fracture zones range in thickness from about 0.5 to 1 foot thick. The applicant encountered these fracture zones in four of the seven new borings performed as part of the ESP subsurface program. In RAI 2.5.4-2, the staff asked the applicant to describe the impact of the fracture zones on the suitability of the site to host safety-related structures. In response to RAI 2.5.4-2, the applicant stated that it would excavate and replace with lean concrete any weathered or fractured zones encountered at the foundation level. In addition, the applicant stated that it would perform multiple borings once the building locations are chosen. These borings will identify whether there are any fracture zones beneath the foundation thicker than those encountered in the ESP borings. The staff concludes that the applicant's proposal to excavate and replace weathered or fractured zones with lean concrete is an adequate method to ensure the stability of the foundation. The replacement of fractured rock with lean concrete is well understood and commonly done to enhance the strength and stability of the rock to support building loads. Accordingly, the NRC staff proposes to include a condition in any ESP that might be issued requiring that the ESP holder and/or an applicant referencing such an ESP replace weathered or fractured rock at the foundation level with lean concrete before initiation of foundation construction. This is **Permit Condition 5.** In addition, the applicant's proposal to perform additional borings, once it has selected building locations, is necessary to ensure that any significant weathered or fractured zones are identified. The need for additional borings to identify any weathered or fractured rock beneath the new foundations is **COL Action Item 2.5-1.** Section 2.5.4 of this SER provides further discussion of the above permit condition and action item as well as the engineering properties of the soil and rock beneath the ESP site.

Based on its review of SSAR Section 2.5.1.2.3 and the applicant's response to the staff's RAIs, cited above, the staff concludes that the applicant adequately described the site area stratigraphy. The staff concludes that SSAR Section 2.5.1.2.3 provides an accurate and thorough description of the site area stratigraphy, with an emphasis on the uppermost layers of rock and residual soil, as required by 10 CFR 52.17 and 10 CFR 100.23. Section 2.5.4 of this SER provides the staff's complete evaluation of the applicant's description of the ESP site subsurface materials and engineering properties.

SSAR Section 2.5.1.2.4 describes the local faults and folds within the metamorphic bedrock underlying and surrounding the site. The applicant identified seven bedrock faults within a 5-mile radius of the ESP site and concluded, based on site area investigations and a review of the published literature, that none of the faults are capable tectonic sources, as defined in RG 1.165. The NAPS licensee thoroughly investigated one of the faults, unnamed fault "a," which traverses the ESP site, following its exposure within the excavations for the abandoned Units 3 and 4. The staff concluded in its 1974 SER for the abandoned Units 3 and 4 that the "North Anna fault zone is neither genetically nor structurally related to any known capable fault," and concurred with Virginia Power's conclusion that fault "a" is not a capable tectonic source.

Subsequent to Virginia Power's investigation, a local geologist mapped fault "a" over a total distance of about 7 miles, which is considerably longer than the original length of about 3000 ft mapped by Virginia Power. In RAI 2.5.3-2, the staff asked the applicant to evaluate the evidence for the continuation of fault "a" beyond the ESP site. In its response, the applicant stated that the local geologist, L. Pavlides, is deceased and did not document an explanation or basis for his mapping of fault "a" beyond the ESP site. The applicant performed aerial reconnaissance, field reconnaissance, and an air photo interpretation of fault "a" and, based on these studies, concluded that no stratigraphic, structural, or geomorphic evidence would support the existence of fault "a" beyond the EPS site. Based on the evidence presented by the applicant, in particular the evidence cited as a result of the field reconnaissance described below, the staff concludes that the applicant has adequately investigated the possible extension of fault "a" beyond the ESP site. During its field reconnaissance, the applicant found no scarps or lineaments along the trace of fault "a" as mapped by Pavlides. The staff notes that the NAPS licensee's trenching of the fault shows that fault "a" is most likely a minor fault or bedrock shear within the Ta River metamorphic suite and that it is very unlikely that such a minor fault could be recognized or mapped over a significant distance without a significant number of exposures. Section 2.5.3 of this SER provides further discussion of fault "a" and RAI 2.5.3-2.

Based on its review of SSAR Section 2.5.1.2.4 and the applicant's response to RAI 2.5.3-2, cited above, the staff concludes that the applicant adequately described the site area structural geology. The staff concludes that SSAR Section 2.5.1.2.4 provides an accurate and thorough description of the site area structural geology, with an emphasis on the structural features within a 5-mile radius of the ESP site, as required by 10 CFR 52.17 and 10 CFR 100.23. Section 2.5.3 of this SER provides the staff's complete evaluation of the applicant's description of the local bedrock faults near the ESP site and their potential for tectonic deformation and producing vibratory ground motion.

SSAR Section 2.5.1.2.5 states that the only geologic hazards associated with the ESP site are (1) vibratory ground motion from regional earthquake activity and (2) potential surface faulting from site area earthquakes. SSAR Sections 2.5.2 and 2.5.3, respectively, discuss these two potential geologic hazards. The corresponding sections of this SER provide the staff's review of these potential hazards. In SSAR Table 1.9-1, the applicant identified the item, "Capable Tectonic Structures or Sources," as an ESP site characteristic and design parameter. This item specifies that there is no fault displacement potential within the investigative area. The staff reviewed the applicant's description of the site area geologic hazards provided in SSAR Section 2.5.1.2.5 and concludes that the ESP site has no fault displacement potential. Section 2.5.3 of this SER provides the staff's evaluation of the fault displacement potential for the ESP site. The staff concludes that SSAR Section 2.5.1.2.5 does not address two other potential site area geologic hazards, namely slope instability and liquefaction, also arising from local or regional earthquakes. However, the applicant addressed these two topics in detail in SSAR Sections 2.5.4 and 2.5.5.

SSAR Section 2.5.1.2.6 describes the engineering behavior of soil and rock at the ESP site. In addition, SSAR Section 2.5.1.2.6 addresses prior earthquake effects, effects of human activities (mineral extraction and ground water withdrawal), construction ground water control, and unforseen geologic features. In its description of the soil engineering behavior, the applicant stated that the high compressibilities and low maximum densities of the saprolite preclude its use as engineered fill at the ESP site. Because of the relatively high initial settlement of the NAPS pumphouse structure, constructed on about 65 ft of saprolite fill, the staff agrees with this conclusion. Accordingly, the staff is proposing **Permit Condition 6**, which would prohibit the ESP holder and/or an applicant referencing such an ESP from using an engineered fill with high compressibility and low maximum density, such as saprolite.

Based on its review of SSAR Section 2.5.1.2.6, the staff concludes that the applicant has adequately described the site soil and rock characteristics. In particular, the applicant thoroughly described zones of weathering and structural weakness within the soils and bedrock, soil and rock types that could be unstable because of their physical properties, and the effects of human activities (e.g., mining extraction and ground water withdrawal) at the site. The staff concludes that SSAR Section 2.5.1.2.6 provides an accurate and thorough description of the local site conditions, as required by 10 CFR 100.23. In addition, because of limited ground water withdrawal and the distance of any mining activity from the site, the staff concludes there is no potential for the effects, such as subsidence or collapse, of human activity that could compromise the safety of the site.

SSAR Section 2.5.1.2.7 describes the ground water at the ESP site in terms of flow direction and hydraulic conductivity. SSAR Section 2.4.12 provides a detailed discussion of the site ground water conditions; Section 2.4.12 of this SER discusses the staff's evaluation of SSAR Section 2.4.12.

2.5.1.4 Conclusions

As set forth above, the staff reviewed the geologic and seismologic information submitted by the applicant in SSAR Section 2.5.1. On the basis of its review, as described above, the staff finds that the applicant provided a thorough characterization of the geologic and seismologic characteristics of the site, as required by 10 CFR 100.23. These results provide an adequate basis to conclude that no capable tectonic faults exist in the plant site area (5 mi) that have the potential to cause near-surface displacement. The staff concurs with the applicant's classification of the CVSZ as a capable seismogenic source zone rather than a tectonic source zone, since no capable tectonic sources have been identified within the CVSZ. In addition, the staff concludes, as described above, that the applicant has identified and appropriately characterized all the seismic sources significant to determining the SSE for the ESP site, in accordance with RG 1.165 and NUREG-0800, Section 2.5.1. Based on the applicant's geological, geophysical, and geotechnical investigations of the site vicinity and site area, the staff concludes that the applicant has properly characterized the site lithology, stratigraphy, geological history, structural geology, and the characteristics of subsurface soils and rocks. The staff also concludes that there is no potential for the effects of human activity (i.e., ground water withdrawal or mining activity) to compromise the safety of the site.

2.5.2 Vibratory Ground Motion

SSAR Section 2.5.2 describes the applicant's determination of the ground motions at the ESP site from possible earthquakes in the site area and region. SSAR Sections 2.5.2.1 through 2.5.2.4 describe the seismic source and ground motion models used by the applicant. SSAR

Section 2.5.2.5 summarizes the seismic wave transmission characteristics of the ESP site. Finally, SSAR Section 2.5.2.6 describes the development of the SSE ground motion for the ESP site.

The applicant stated that the information provided in SSAR Section 2.5.2 complies with NUREG-0800 and uses the procedures recommended in RG 1.165. In addition, the applicant based its seismic ground motion calculations on the EPRI seismic source model for the CEUS. According to RG 1.165, applicants may use the seismic source interpretations developed by LLNL in 1993 or those developed by EPRI as inputs for a site-specific analysis. RG 1.165 also recommends a review and update, if necessary, of both the seismic source and ground motion models used to develop the SSE ground motion for a given site.

2.5.2.1 Technical Information in the Application

2.5.2.1.1 Seismicity

SSAR Section 2.5.2.1 describes both the review and update of the earthquake catalog used to define the seismic sources for the ESP site. The applicant used the original EPRI seismicity catalog, which is complete only through 1984. Therefore, in addition to reevaluating the EPRI catalog, the applicant added seismicity data for the time period from 1985 through 2001 (see SER Figure 2.5.1-4).

The seismicity catalog used for the original EPRI study compiled the data from the seismic networks in the CEUS. Therefore, to develop the EPRI catalog, it was necessary to remove duplicate earthquakes, ensure a consistent magnitude scale (m_b), remove data from events other than earthquakes (e.g., mine blasts and sonic booms), and perform a final check to ensure that the catalog includes significant historic events. To update the 1984 EPRI seismicity catalog, the applicant focused on sources of seismic data in the region surrounding the ESP site. The applicant stated that the most complete regional catalog for recent earthquakes is published by the Virginia Polytechnic Institute and State University (VT) and maintained by Martin Chapman of VT. The VT seismic catalog is complete through 2001 for Virginia, Maryland, Delaware (south of latitude 40° N), West Virginia (south of latitude 40° N), North Carolina, South Carolina, Georgia, Florida, Alabama, Tennessee (east of longitude 88° W), and Kentucky (east of longitude 88° W). However, the VT seismic network and database do not completely cover the region surrounding the ESP site. To supplement the VT catalog, the applicant used the seismic catalog from the Advanced National Seismic System (ANSS) for latitudes of 39.7° N and higher. The updating of seismicity in the ESP site region bounded by latitude 35° to 41° N and longitude 74° to 82° W resulted in the identification of 30 additional earthquakes (24 from the VT catalog and 6 from the ANSS catalog).

2.5.2.1.2 Geologic Structures and EPRI Seismic Source Model for the Site Region

SSAR Section 2.5.2.2 describes the seismic source interpretations from the 1989 EPRI study and the evaluation of new information on seismic sources since the EPRI study. In general, the applicant found that the 1989 EPRI seismic source models did not need to be updated for the ESP site seismic source characterization.

Six independent earth science teams (ESTs) developed the characterization of CEUS seismic sources in the EPRI project. These ESTs evaluated geological, geophysical, and seismological data to model the occurrence of future earthquakes and analyze earthquake hazards at nuclear power plant sites in the CEUS. The six ESTs involved in the EPRI project included (1) the Bechtel Group, (2) Dames and Moore, (3) Law Engineering, (4) Roundout Associates, (5) Weston Geophysical Corporation, and (6) Woodward-Clyde Consultants. EPRI implemented the results of the seismic source characterizations from each of the ESTs in a PSHA for nuclear power plant sites in the CEUS. SSAR Tables 2.5-5 through 2.5-10 summarize the seismic source information developed by each of the ESTs for sources in the region surrounding the ESP site. This information includes the M_{max}, closest distance to the ESP site, probability of activity, and an indication as to whether new information regarding the seismic source has been identified since the original EPRI seismic hazard analyses. The application does not present earthquake recurrence values for each of the seismic sources because the recurrence values were computed for each 1-degree latitude and longitude cell that intersects any portion of a seismic source and, as such, many larger source zones have multiple recurrence values.

In RAI 2.5.2-4(a), the staff asked the applicant to provide additional seismicity parameters, beyond those shown in SSAR Tables 2.5-5 through 2.5-11, for the seismic source zones surrounding the ESP site. In response to RAI 2.5.2-4(a), the applicant provided the seismic source recurrence values used for the EPRI study for the 1-degree latitude and longitude cell encompassing the ESP site region. SER Section 2.5.2.3.2 provides a complete description of the applicant's response to RAI 2.5.2-4(a) and the staff's review of the applicant's response.

The applicant stated the following concerning the seismic source characterizations of the original EPRI study:

> Except for the three specific cases described earlier [below], no new seismological, geological, or geophysical information in the literature published since the publication of the 1986 EPRI source model (Reference 120) suggests that these sources should be modified. The three cases where new information requires modification of the EPRI source characterizations is the addition of the northern segment of the [East Coast Fault System] ECFS (ECFS-N) as a new potential seismic source, the new recurrence and geometry parameters for the existing Charleston source (modeled after the southern segment of the [East Coast Fault System] ECFS (ECFS-S), and the new recurrence parameters for the New Madrid source.

SSAR Sections 2.5.2.2.2 through 2.5.2.2.7 briefly describe the seismic source characterizations made by the six ESTs for each of the sources surrounding the ESP site. Since the largest contributor to the seismic hazard at the ESP site is the CVSZ, the applicant described its source characterization by the six ESTs in SSAR Section 2.5.2.2.8. The six ESTs characterize the largest M_{max} earthquake for the CVSZ as m_b 6.6 to 7.2, with each magnitude value accompanied by a weight. For example, the Dames and Moore EST assigned the M_{max} values for the CVSZ as m_b 6.6 and 7.2, with a corresponding weight for these two magnitudes of 0.8 and 0.2, respectively. The applicant stated that, since the EPRI study, two paleoliquefaction features have been found within the CVSZ, and that these new observations are "consistent with the M_{max} values and recurrence parameters assigned by the EPRI teams." Furthermore, in SSAR Section 2.5.2.2.8, the applicant concluded the following:

> The lack of widespread liquefaction features in the 300 km of stream exposures searched within the CVSZ, despite the presence of mid-to-late-Halocene potentially liquefiable deposits, has led some researchers (Reference 71) to conclude that it is unlikely that any earthquakes have occurred in the area investigated in excess of M~7 during the Holocene.

In RAI 2.5.2-7, the staff asked the applicant to describe how the modern and historical seismicity of the CVSZ is distributed within either a specific source zone or a background source zone. In its response, the applicant described the source model used by each of the six EPRI teams to characterize the CVSZ. SER Section 2.5.2.3.2 provides a complete description of the applicant's response to RAI 2.5.2-7 and the staff's review of the applicant's response.

In RAI 2.5.2-4(b), the staff asked the applicant to justify its decision not to update the M_{max} assigned to the CVSZ for the 1989 EPRI seismic source models, considering the 1994 EPRI study, "Seismotectonic Interpretation and Conclusion from the Stable Continental Region Database." In its response, the applicant stated that EPRI initiated the 1994 study in the mid-1980s specifically for use by the EPRI teams in their development of the 1989 EPRI seismic source models. EPRI provided the preliminary results of the 1994 study to each of the EPRI teams for their use in assigning M_{max} values in stable continental regions (SCRs), such as the ESP site region. As such, the EPRI teams used the estimates of M_{max} and source zone geometry drawn from the preliminary results of the 1994 EPRI study for their 1989 seismic source models. SER Section 2.5.2.3.2 provides a complete description of the applicant's response to RAI 2.5.2-4(b) and the staff's review of the applicant's response.

SSAR Section 2.5.2.2.9 describes the post-EPRI PSHA studies within the North Anna site region for comparison with the PSHA completed as part of the ESP application. Since the EPRI seismic hazard project, researchers have completed three PSHA studies that overlap or include the seismic sources within the North Anna site region. These three studies include the following:

- Savannah River nuclear site (Ref. 125, SSAR Section 2.5)
- seismic hazard of Virginia (Ref. 126, SSAR Section 2.5)
- USGS National Seismic Hazard Mapping Project (Ref. 127, SSAR Section 2.5)

The PSHA performed for the Savannah River nuclear site in South Carolina specifies sources, recurrence rates, focal depths, and M_{max} values for earthquake sources in the southeastern United States. As part of the Savannah River PSHA, Bollinger (Ref. 125, SSAR Section 2.5) identified three seismic sources that fall within the North Anna site region. These sources include the CVSZ, the Giles County seismic zone, and a complementary background zone. For the CVSZ, the Savannah River PSHA assigns an M_{max} of m_b 6.4, which is comparable to the range of M_{max} values given for the CVSZ by the EPRI teams. For the Giles County seismic zone and complementary background zone, the Savannah River PSHA assigns maximum values of 6.3 and 5.7, respectively. These M_{max} values are also similar to those used by the EPRI teams for these two source zones.

The applicant stated that researchers at VT (Ref. 126, SSAR Section 2.5) performed a seismic hazard assessment of Virginia in 1994 on a county-by-county basis. The study defined a total of 10 seismic sources based primarily on patterns of seismicity, with 7 of the 10 sources located within the region surrounding the North Anna site. For each source zone, the authors of the study assumed an M_{max} of m_b 7.25. This M_{max} is based on the assumption that an earthquake similar to the one that occurred in 1868 in Charleston, South Carolina (m_b 6.8 to 7.5), could occur in any of the sources within the North Anna site region. The applicant stated that this M_{max} is consistent with the range of M_{max} values that the EPRI teams assigned to the CVSZ and Giles County seismic zones.

The third PSHA performed after the EPRI 1989 study was the 2002 USGS National Seismic Hazard Mapping Project. The 2002 USGS national seismic hazard maps are the updated 1996 USGS seismic hazard maps that incorporate changes in the recurrence and geometry of the Charleston, South Carolina, seismic source, as well as the recurrence and M_{max} assigned to the New Madrid seismic source zone. Rather than defining many local seismic source zones, the USGS hazard study includes only a small number of sources surrounded by larger background zones. Within the ESP site region, the USGS model defines a single source zone, the Extended Margin Background Zone, which covers nearly the entire eastern and southeastern United States. The M_{max} value assigned to the Extended Margin Background Zone by USGS is 7.5, which corresponds to m_b 7.2. The applicant stated that this M_{max} value is consistent with the range of maximum values assigned to the CVSZ by the EPRI teams.

2.5.2.1.3 Correlation of Seismicity with Geologic Structures and EPRI Sources

As part of the review and update of the 1989 EPRI seismic source model, the applicant compared the updated seismicity (1985 through 2001) with the earlier EPRI seismicity catalog (1627 through 1984). As a result of this comparison, the applicant concluded that the updated catalog does not show (1) any earthquakes within the site region that can be associated with a known geologic structure, (2) a unique cluster of seismicity that would suggest a new seismic source outside of the EPRI source model, (3) a new pattern of seismicity that would warrant significant revision to the EPRI seismic source geometry, (4) an increase in the M_{max} for any of the EPRI seismic sources, and (5) any changes to the recurrence values for the EPRI seismic sources.

2.5.2.1.4 1989 EPRI Probabilistic Seismic Hazard Analysis, Deaggregation, and 1-Hz, 2.5-Hz, 5-Hz, and 10-Hz Spectral Velocities

SSAR Section 2.5.2.4 describes the confirmation of the 1989 EPRI PSHA results for North Anna. For its confirmation, the applicant used the peak ground acceleration (PGA) hazard curves for comparison with the 1989 EPRI PSHA results for North Anna. The applicant found that the average difference in annual probability of ground motion exceedance is +1.1 percent, which corresponds to a 0.3 to 0.7 percent increase of the ground motion amplitude. This difference is much less than the total uncertainty in seismic hazard calculations, and, as such, the applicant concluded that the current PSHA for the ESP site correctly models the seismic sources and ground motion equations. To further confirm the accuracy of the current PSHA, the applicant also replicated the 1-, 2.5-, 5-, and 10-Hertz (Hz) spectral velocity hazard curves using the 1989 EPRI seismic sources and ground motion models. In addition, using the procedure described in RG 1.165, the applicant calculated the controlling earthquakes for the ESP site using the 1989 EPRI results. The low-frequency controlling earthquake magnitude and distance are M_w 5.9 and 25 km, respectively, and the high-frequency controlling earthquake magnitude and distance are M_w 5.5 and 18 km, respectively. The applicant used these controlling earthquakes for comparison with the updated PSHA results for the ESP site presented in SSAR Section 2.5.2.6.1.

2.5.2.1.5 Seismic Wave Transmission Characteristics of the Site

SSAR Section 2.5.2.5 briefly summarizes the subsurface model used for the ESP site. The foundation materials are divided into the following five zones from surface to bedrock:

- residual clays and clay silts (Zone I)
- weathered saprolite (Zone IIA)
- saprolite (Zone IIB)
- weathered rock (Zone III)
- parent rock (Zone IV)

The applicant stated that the containment (reactor building) and primary safety-related structures would be founded on sound bedrock, either Zone IV or Zone III-IV (slightly to moderately weathered rock). The applicant also stated that other safety-related structures (possibly the diesel generator building and certain tanks) may be founded on Zone III weathered rock or Zone II saprolitic soils.

Section 2.4.5.7 of the SSAR presents a detailed description of the seismic wave transmission characteristics of each of the above soil and rock layers. The description includes the shear wave velocity, as well as the variation of shear modulus and damping with strain for each of the zones.

In RAIs 2.5.2-1(c) and 2.5.2-8, the staff asked the applicant to explain how it factored the properties of the site-specific subsurface materials into the determination of the SSE. In its responses, the applicant stated the following:

> The SSE spectrum is calculated directly using the EPRI 2003 ground motion models. For the North Anna ESP site, the selected SSE directly incorporates the hard rock foundation assumption of the EPRI 2003 ground motion models (a shear-wave velocity of 2.8 km/s or about 9,200 ft/s). The containment (reactor) building and primary supporting safety-related structures would be founded on sound bedrock, either Zone IV or Zone III-IV materials (see SSAR Section 2.5.2.5) for which this shear wave velocity is a good approximation. Therefore, site-specific materials are factored into the determination of the SSE by recognizing that the hazard analysis performed to develop the SSE uses attenuation relations that are directly applicable to specific subsurface conditions at the North Anna site.

As set forth in the DSER, the staff considered the applicant's response above to be inadequate based on a comparison of the hard rock shear wave velocity (9200 ft/s) assumed by the EPRI 2003 ground motion models and the bedrock Zone III-IV shear wave velocity (3300 ft/s) beneath the ESP site. DSER Open Item 2.5-2 covered the necessity to include the local site conditions in the determination of the SSE. As a result of Open Item 2.5-2, the applicant reran its analysis to determine the seismic wave transmission characteristics of the site. The applicant's new analysis used a rock subsurface profile that extends from the top of Zone III-IV bedrock to a depth of 160 ft under the site where the shear wave velocity reaches about 9200 ft/s. The applicant used the ESP rock subsurface profile to estimate the amplification of the SSE ground motion at a control point located at the top of competent Zone III-IV rock. The following SER Section (2.5.2.1.6) provides a complete description of the applicant's response to Open Item 2.5-2, and SER Section 2.5.2.3.5 provides the staff's evaluation of the applicant's response.

2.5.2.1.6 Safe-Shutdown Earthquake Ground Motion

SSAR Section 2.5.2.6 describes the development of the SSE ground motion for the ESP site. The first four subsections of SSAR Section 2.5.2.6 describe the updating of the 1989 EPRI PSHA in terms of (1) a new regional earthquake catalog, (2) new M_{max} information, (3) new seismic source characterizations, and (4) new ground motion models. The subsequent subsections of Section 2.5.2.6 describe (1) the controlling earthquakes, (2) the selected SSE ground motion, (3) sensitivity studies, and (4) the future modification of the selected SSE spectrum.

SSAR Section 2.5.2.6 addresses the new geoscience information (new seismic sources, new magnitudes, new recurrence intervals, new ground motion models) by examining the effect of this new information on the median seismic hazard at levels of 10^{-5} per year. The applicant used the 1989 EPRI seismic sources and ground motion models to compare the effect of this new information on the seismic hazard at the ESP site with the seismic hazard developed for North Anna.

New Regional Earthquake Catalog

This section compiles the seismic sources surrounding the ESP site that contribute 99 percent of the seismic hazard, using both the PGA hazard results and the 1-Hz spectral velocity hazard results. The applicant used this compilation of seismic sources from the 1989 EPRI PSHA to determine whether the seismic activity rates used in the 1989 EPRI study are still adequate. The applicant examined recent seismic activity rates using earthquakes recorded in the region since 1984 and compared these rates to those used in the 1989 EPRI PSHA. The results of this comparison show that recent seismicity, recorded from 1985 to 2001, indicates that seismic activity rates have decreased for the sources contributing most to the ESP site. Therefore, the applicant used the seismic activity rates derived from the 1989 EPRI study to calculate the seismic hazard at the ESP site.

New Maximum Magnitude Information

This section describes the applicant's review of the geologic and seismologic data published since the 1986 EPRI seismic source model to determine if changes to the M_{max} values for any of the seismic source zones are needed. The applicant stated that the M_{max} used for the EPRI source models relied on an EPRI study (Ref. 195, SSAR Section 2.5) of large earthquakes occurring worldwide within SCRs. Based on its review, the applicant concluded that the range of M_{max} values assigned by the EPRI teams for the Charleston, South Carolina, seismic source is too low. For the Charleston seismic source, the applicant identified a new geologic structure as the possible source of the 1886 Charleston earthquake, referred to as the ECFS-S. For the

ECFS-S M_{max} values, the applicant decided to use the 2002 USGS values and weights. These M_{max} values range from M_w 6.8 to 7.5. The Charleston source M_{max} values used by the six EPRI teams for the 1989 PSHA range from M_w 6.5 to 8.0.

New Seismic Source Characterizations

This section describes the applicant's review of the geologic and seismologic data published since the 1989 EPRI seismic source model to determine whether any new seismic sources have been postulated or whether significant changes to the characterizations of previously identified sources are needed. The applicant concluded that three changes to the 1989 EPRI seismic source characterizations were necessary, namely (1) identification of a postulated ECFS-N, (2) revision to the recurrence interval and source geometry of the Charleston seismic source, and (3) revision to the recurrence interval of the New Madrid seismic source.

As modeled, the ECFS runs along the Atlantic seaboard and consists of the ECFS-N, ECFS-C, and ECFS-S (see SER Figure 2.5.1-6). The ECFS-N is located approximately 70 miles southeast of the ESP site and was not previously included in the 1989 EPRI PSHA. For the ECFS-N, the applicant assumed a probability of existence of 0.1 and a probability of activity (given existence) of 0.1. For the ECFS-N, the applicant adopted the M_{max} parameters and weights used in the 2002 USGS national seismic hazard map for the Charleston source. The applicant selected the recurrence values and weights of 550 years (0.1), 25,000 years (0.5), and 50,000 years (0.4), respectively. The applicant stated that it assigned low weights to the probability of existence and probability of activity because the existence of the fault is not well documented and is highly uncertain. In addition, no geologic, geomorphic, or seismologic evidence indicates that the fault exists as a tectonic feature or, if it does exist, that it is active.

New data published since the original EPRI study have resulted in revisions to the recurrence interval and source geometry for the Charleston seismic source. As stated earlier, the applicant adopted the M_{max} values used by the 2002 USGS national hazard maps for the Charleston seismic source. In addition to the M_{max} values, the applicant also reduced the recurrence interval for the Charleston source from several thousand years, used by the 1989 EPRI PSHA, to 550 years. The applicant stated that it based the reduction in the recurrence interval for the Charleston seismic source on recent paleoliquefaction studies, which provide evidence of previous earthquakes in the Charleston source area. In addition to M_{max} values and recurrence intervals, the applicant used the ECFS-S as an alternative source geometry for the Charleston source. The applicant also assumed that the mean recurrence interval of 550 years applies to the M_{max} values. The applicant stated that this approach is conservative because the mean recurrence interval may not be directly associated with earthquakes as large as the assumed M_{max} values.

In RAI 2.5.2-5, the staff asked the applicant to explain how it incorporated the alternative characterization of the ECFS-S into the final PSHA. In its response, the applicant stated that it evaluated the alternative characterization of the ECFS-S, both independently and additively, to conservatively assess the maximum possible change to hazard at the North Anna ESP site from this newly postulated source. The revisions to the ECFS-S include a shorter recurrence interval (550 years) and different weights for the M_{max} (M_w 6.8 to 7.5). The applicant added the ECFS-S to the source models of each of the six EPRI teams for the final PSHA. SER Section 2.5.2.3.4 provides a complete description of the applicant's response to RAI 2.5.2-5 and the staff's evaluation of the applicant's response.

SSAR Section 2.5.2.6.5 states that the applicant examined the effects of the new characterization of the ECFS-N and ECFS-S fault segments by calculating the seismic hazard from these two fault segments and comparing this seismic hazard to that predicted from the 1989 EPRI seismic sources. The applicant calculated the seismic hazard from these two fault segments using the 2003 EPRI ground motion models rather than the earlier 1989 ground motion models. As shown in SSAR Figures 2.5-40 and 2.5-41, the ECFS-S fault increases the total median and mean hazard for 1-Hz spectral acceleration by several percent at the 10^{-5} hazard level. The ECFS-N fault segment, for which the applicant assigned a 10 percent probability of existence and activity, does not contribute to the overall hazard. For higher frequency ground motion (i.e., 10-Hz spectral acceleration), neither the ECFS-S nor the ECFS-N fault segments contribute significantly to the overall seismic hazard. SSAR Section 2.5.2.6.5 states that this results from the domination of the higher frequency ground motion by seismic sources closer than the distant ECFS. The ECFS-N fault segment is 70 miles southeast of the ESP site, and the ECFS-S is 300 miles south of the ESP site.

New Ground Motion Models

To estimate the ground motion at the ESP site from each of the seismic sources, the applicant used the new 2003 EPRI-sponsored study that compiles and evaluates 13 new ground motion attenuation models for the CEUS (Ref. 116, SSAR Section 2.5). The previous EPRI PSHA used only three ground motion attenuation models.

For lower frequency ground motion (i.e., 1-Hz spectral acceleration), the new ground motion models result in median hazard results that are about the same as the hazard results derived using the 1989 ground motion models. In contrast, the 2003 mean hazard is significantly lower than the 1989 mean hazard. In addition, for higher frequency ground motion (i.e., 10-Hz spectral acceleration), SSAR Section 2.5.2.6.5 states that both the median and mean hazards increase significantly at annual frequencies of 10^{-5}. Figure 2.5-44 in the SSAR compares a 10-Hz seismic hazard for both the 1989 ground motion models and the 2003 ground motion models. SSAR Section 2.5.2.6.5 provides the following rationale for the higher hazard for higher frequency ground motion determined by the newer model:

> A major difference between the 1989 and 2003 ground motion models is that the estimates of aleatory [random] uncertainty are larger in the 2003 study. In 1989, a standard deviation of natural log (ground motion) of 0.5 was used for all frequencies, whereas in 2003, values of 0.6 and 0.7 are common (they vary depending on magnitude, distance, and frequency). At annual frequencies of 10^{-5}, which are sensitive to the tails of the ground motion aleatory distribution, this difference in standard deviation increases seismic hazard. This would likely be true for any CEUS location. A compensating factor at low frequencies (1 and 2.5 Hz) [1 Hz] is the use of ground motion models that reflect a two-corner source, which acts to reduce low frequency [1 Hz] ground motion estimates from those used in 1989. Thus the median 1 Hz seismic hazard is about the same for both models. The mean amplitudes using the 2003 ground motion models are closer to the median amplitudes than is the case for the 1989 models, reflecting convergence on what are reasonable models to use for ground motion estimation in the eastern US. In 1989, the ground motion models were quite diverse, with one model developed by estimating peak ground acceleration and

velocity, then using spectral amplification factors to estimate spectral amplitudes. In 2003, the available models estimate spectral amplitudes directly.

PSHA and Controlling Earthquakes

Using the 2003 EPRI ground motion models and adding the ECFS-S fault segment, the applicant calculated the PSHA results for the ESP site. Table 2.5-22 of the SSAR, reproduced below, compares the 1989 EPRI PSHA and the 2003 PSHA results.

Table 2.5.2-1 Updated Seismic Hazard Results at ESP Site

Frequency	Median/Mean	Updated PSHA	1989 PSHA	Difference
1 Hz	10^{-5} median	0.096 g	0.091 g	6%
	10^{-5} mean	0.134 g	0.219 g	-39%
2.5 Hz	10^{-5} median	0.316 g	0.232 g	36%
	10^{-5} mean	0.364 g	0.519 g	-30%
5 Hz	10^{-5} median	0.639 g	0.439 g	46%
	10^{-5} mean	0.735 g	0.753 g	-2%
10 Hz	10^{-5} median	1.020 g	0.660 g	55%
	10^{-5} mean	1.216 g	0.827 g	47%

As shown in Table 2.5.2-1 above, the largest difference is at 10 Hz, where the updated PSHA indicates higher ground motion amplitudes for the 10^{-5} median and mean by 55 percent and 47 percent, respectively. At 1 Hz, 2.5 Hz, and 5 Hz, the updated PSHA shows a higher median 10^{-5} hazard, but a lower mean 10^{-5} hazard.

Selected SSE Ground Motion

The method for determining the SSE for a site, as described in RG 1.165, is based on the use of a reference probability. The basis for the procedure in RG 1.165, as well as the determination of the reference probability, is that existing nuclear power plants do not represent an undue risk to the health and safety of the public. As such, using the existing plants as a reference, RG 1.165 recommends a procedure to determine the seismic design basis for future plants. The reference probability is the average probability of exceeding the SSE ground motion at 5 Hz and 10 Hz, using either the 1993 LLNL PSHA or the 1989 EPRI PSHA. The NRC staff calculated a reference probability level for 29 nuclear power plant sites in the CEUS; the median reference probability for these 29 sites, using median hazard results, is 10^{-5} per year. A similar value was obtained using both the 1993 LLNL and the 1989 EPRI PSHA level;

therefore, RG 1.165 endorses both the LLNL and the EPRI PSHA results as suitable for seismic hazard estimation for future siting.

To determine the site SSE, the applicant used the method described in RG 1.165, but with a higher reference probability. In RAI 2.5.2-1(d), the staff asked the applicant to justify this higher reference probability. The applicant cited Section B.3 in Appendix B to RG 1.165 and the following three factors to justify changing the reference probability:

(1) The revised EPRI ground motion models (Ref. 116, SSAR Section 2.5) indicate generally higher ground motions and aleatory uncertainties at higher frequency amplitudes of interest than previous models.

(2) The mean recurrence time for large earthquakes in the New Madrid, Missouri, region and in the Charleston, South Carolina, region has decreased since the EPRI and LLNL studies in the 1980s.

(3) Use of the mean hazard instead of the median hazard results in a higher reference probability because mean hazard curves lie above median hazard curves.

The applicant stated that the combined effect of these three factors would increase the reference probability by a factor of at least 5. Therefore, the applicant selected a mean hazard value of 5×10^{-5} as its reference probability. The applicant then deaggregated the PSHA results using the new reference probability to determine the controlling earthquakes for the ESP site. The controlling earthquakes for the ESP site have a magnitude of 5.4 at 12 miles (19.31 km) and a magnitude of 7.2 at 191 miles (307.4 km). The first magnitude-distance pair is the high-frequency (i.e., 5 and 10 Hz) controlling earthquake and is consistent with an earthquake from the CVSZ. The second magnitude-distance pair is the low-frequency (i.e., 1 and 2.5 Hz) controlling earthquake and is consistent with an earthquake from the ECFS-S fault. Figures 2.5.2-1 and 2.5.2-2, reproduced from SSAR Figures 2.5-49 and 2.5-50, respectively, depict the results of the deaggregation of the PSHA results.

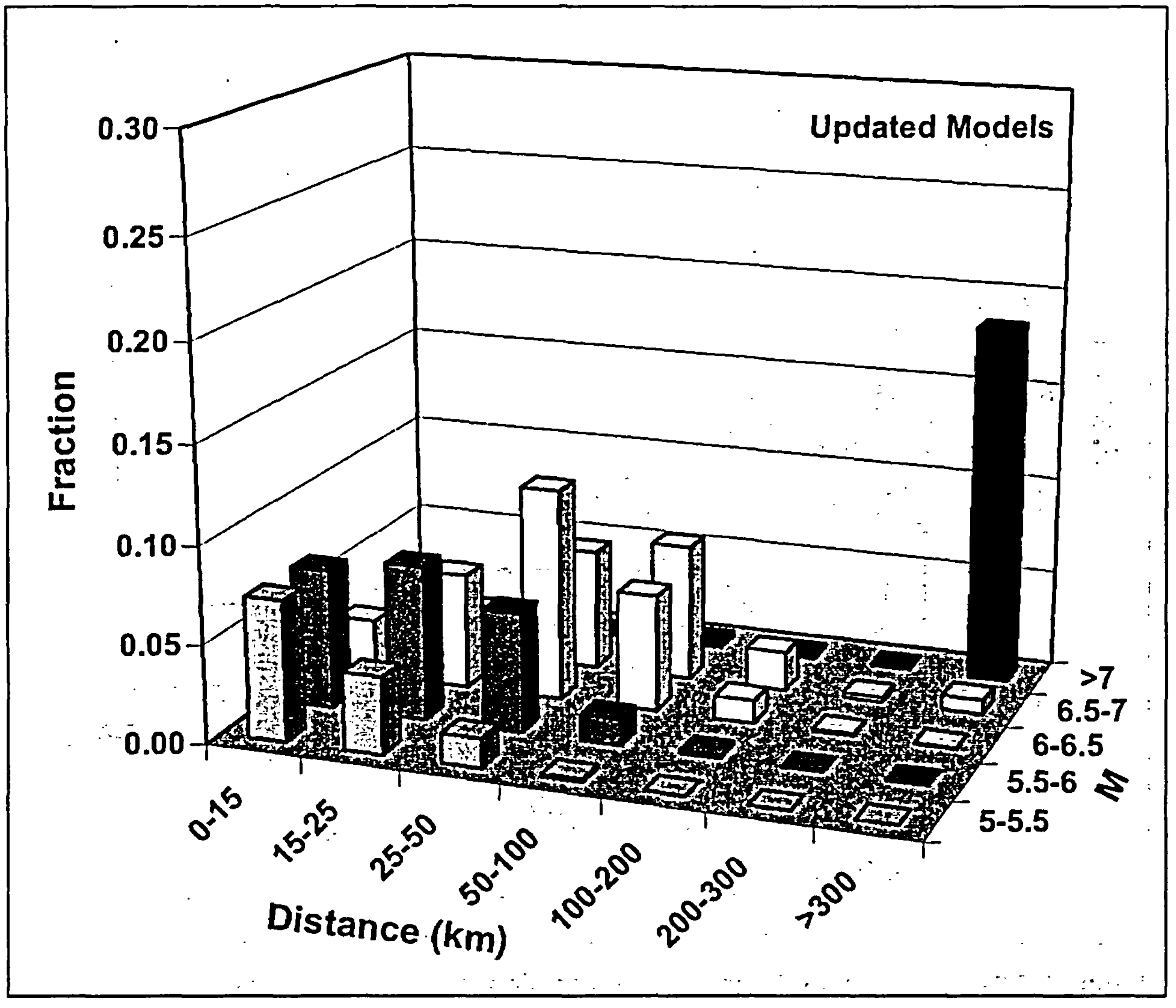


Figure 2.5.2-1 Magnitude-distance deaggregation for low frequencies (1 and 2.5 Hz) at a mean annual frequency of $5x10^{-5}$ using updated source and ground motion models

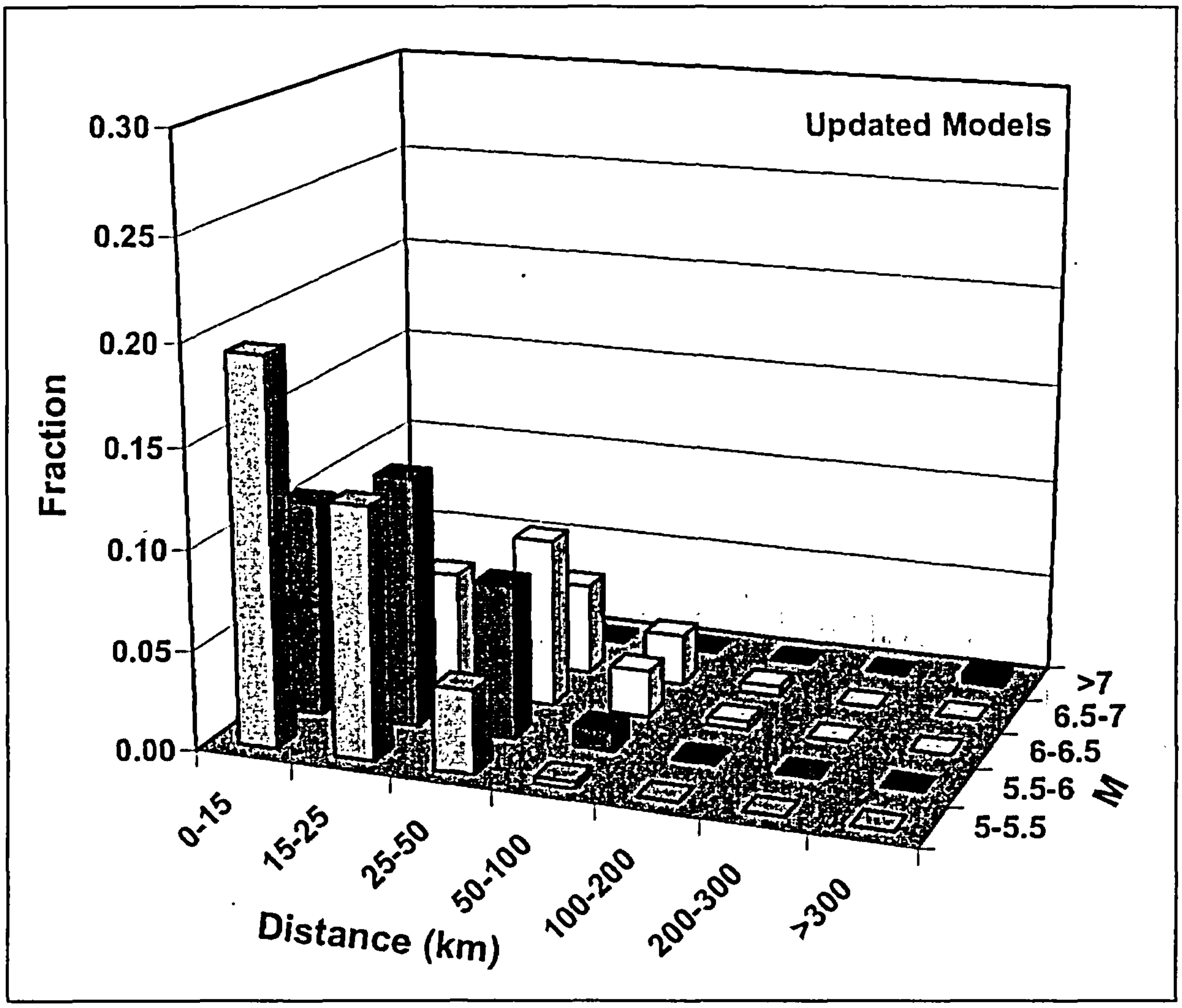


Figure 2.5.2-2 Magnitude-distance deaggregation for high frequencies (5 and 10 Hz) at a mean annual frequency of 5×10^{-5} using updated source and ground motion models

To determine these two controlling earthquakes, the applicant followed the procedure in Appendix C to RG 1.165, using the higher reference probability and the mean PSHA hazard results rather than the median results. Using the two controlling earthquakes, the applicant then determined two ground motion response spectra using the EPRI 2003 ground motion relationships and scaling the two spectra to the appropriate ground motion amplitudes. Figure 2.5.2-3, reproduced from SSAR Figure 2.5-48, shows the hard rock (9200 ft/s) ground motion response spectra for the two controlling earthquakes.

In addition to using the methodology described in RG 1.165 to determine the SSE ground motion, the applicant chose to use an alternative approach, described as a performance-based approach. In RAI 2.5.2-1, the staff asked the applicant to explain how the performance-based approach meets the requirements of 10 CFR 100.23, which provides the geologic and seismic siting criteria, as well as a definition of the SSE. In its response, the applicant explained how the performance-based approach conforms to the requirements of 10 CFR 100.23. In RAI 2.5.2-9, the staff asked the applicant for further details on the performance-based approach to supplement the information provided in SSAR Section 2.5.2.6. In its response, the applicant provided further justification for the performance-based approach, including the derivation of some key relationships. Section 2.5.2.3.6 of this SER discusses this further.

Selection of Enveloping Horizontal SSE Spectrum

Initially, to determine the final SSE for the ESP site, the applicant enveloped the two controlling earthquake ground motion response spectra and the performance-based spectrum. Figure 2.5.2-3, reproduced from SSAR Figure 2.5-54A, shows these spectra. However, as a result of Open Item 2.5-2, described above in the previous SER subsection, the applicant incorporated the local site geologic properties into its determination of the final SSE. The applicant's new analysis used a rock subsurface profile that extends from the top of Zone III-IV bedrock (21 ft depth) to depths at which the shearwave velocity in the bedrock under the site reaches about 9200 ft/s (160 ft depth). The applicant used this best-estimate profile to estimate the amplification of the SSE ground motion at a control point located at the top of competent Zone III-IV rock. The applicant selected this control point at the top of Zone III-IV rock to be consistent with Section 3.7.1 of NUREG-0800, which states that the control point for sites with a thin soil layer is specified on "an outcrop or a hypothetical outcrop at a location on the top of the competent material."

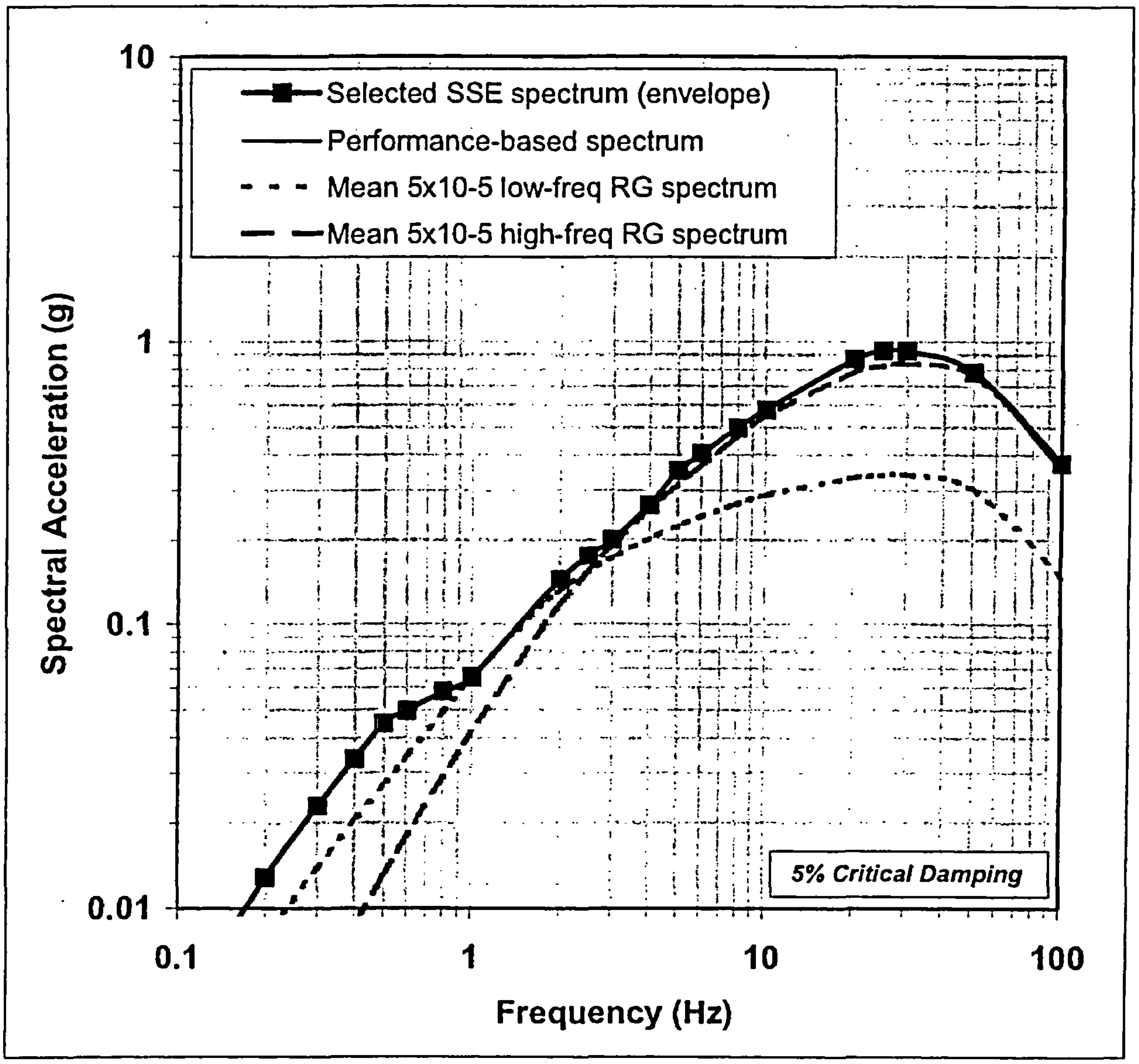


Figure 2.5.2-3 Comparison of performance-based spectrum, mean $5x10^{-5}$ scaled spectra, and selected SSE spectrum (which overlaps the performance-based spectrum and envelops the other two)

To determine the control point SSE at the top of Zone III-IV rock, the applicant (1) developed a shear wave velocity profile for the ESP site, (2) generated alternative randomized rock columns to incorporate the variability in the rock properties, (3) selected seed earthquake time histories, and (4) performed the final ground response analysis.

The applicant's shear wave velocity profile is based on its subsurface exploration for the ESP site and Virginia Power's subsurface explorations for the existing units. For these explorations, the applicant made shear wave velocity measurements mainly at 5-ft depth intervals, but sometimes at 10-ft depth intervals. The applicant also defined the material properties of density, Poisson's ratio, and the behavior of shear wave velocity and material damping as a function of strain. SSAR Section 2.5.4.7 describes the subsurface shear wave velocity and related material property information for the ESP site.

The applicant developed 50 alternative randomized rock columns by varying the material properties described above. The applicant generated 50 randomizations of the generic ESP site rock column velocity profile between elevations with shear wave velocities of 9200 ft/s and 3300 ft/s. The applicant kept the same damping value for all sublayers within any given profile but varied the damping value between one artificial rock column and the next.

Next, the applicant selected two seed time histories to match the low- and high-frequency controlling earthquake response spectra shapes (see Figure 2.5.2-3). The applicant selected these two time histories using the controlling earthquake magnitude and distance values from the database of CEUS time histories given in NUREG/CR-6728 (Ref. 9, SSAR Section 2.5).

To perform the final ground response analysis, the applicant used the two low-frequency and high-frequency input hard rock motions for each of the 50 artificial rock profiles. The applicant modeled the site using horizontal layers, each 7.5 ft thick, overlying a uniform half-space of hard bedrock (V_s at 9200 ft/s). Figure 2.5.2-4, reproduced from Figure 8 in the March 30, 2005, response to Open Item 2.5-2, shows the 50 response spectra for the high- and low-frequency time histories at the control point at the top of Zone III-IV rock (model layer 1).

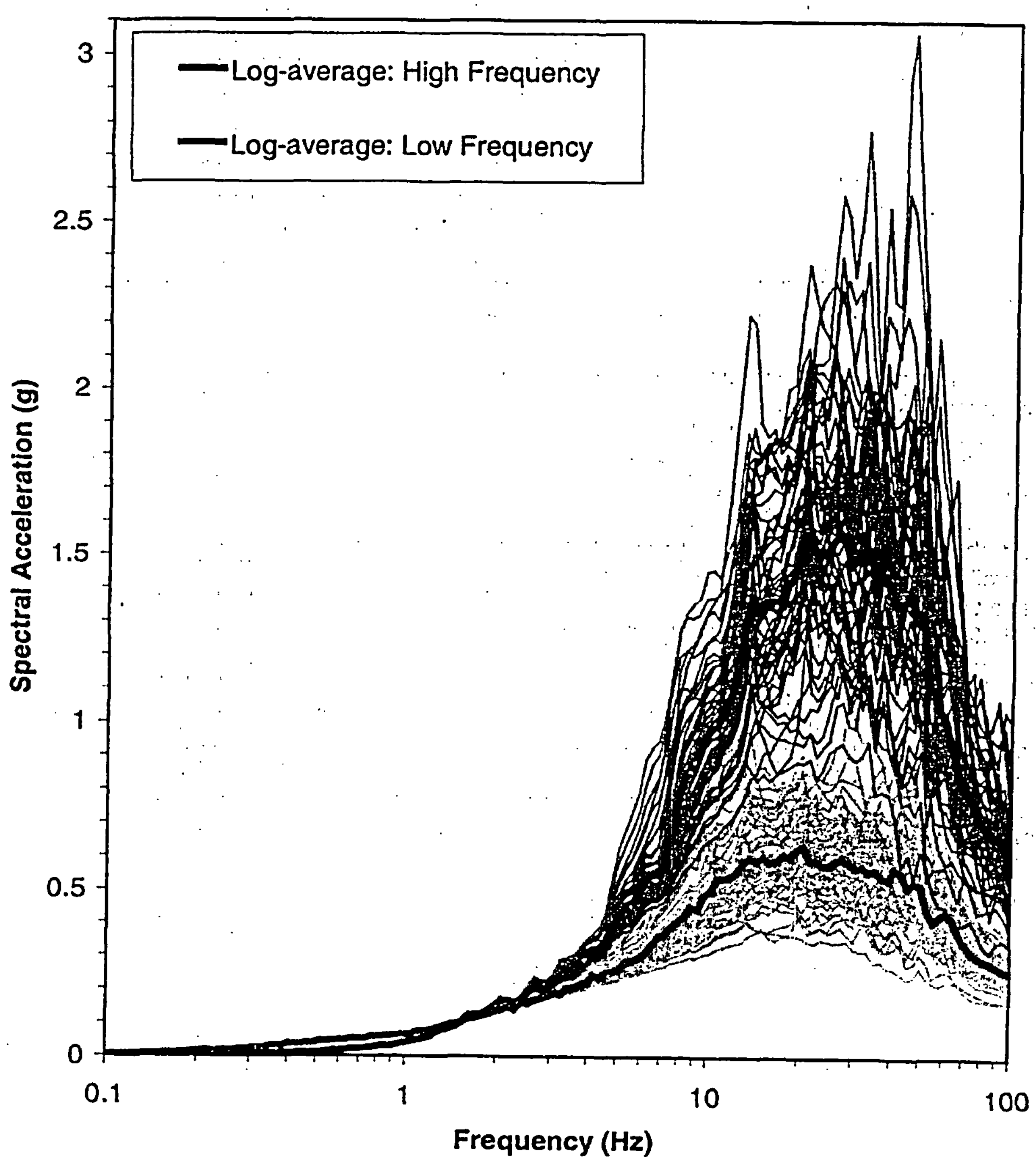


Figure 2.5.2-4 Response Zone III-IV control point (Elevation 250 ft., Layer 1) – 5% Critical Damping ARS – High Frequency (upper dark gray group) and Low Frequency (lower light gray group) time histories. Log-average of each set of 50 response spectra for the high and low frequency time histories indicated by the heavy blue and red lines, respectively.

Next, the applicant fit a smooth function through the enveloped log-average spectrum, which is shown in Figure 2.5.2-4. This smooth function is the final ESP site horizontal SSE ground motion spectrum, which the applicant has defined at the control point at the top of Zone III-IV rock. The spectral acceleration at 25 Hz for the ESP site horizontal SSE is 1.476g and the PGA at 100 Hz is 0.555g.

In order to develop the transfer function between the hard rock (V_s 9200 ft/s) at a depth of 161 ft and the control point at the top of Zone III-IV (V_s 3300 ft/s), the applicant computed the ratio of the hard rock response spectrum and the SSE spectrum at 21 frequency points. The transfer function provides the ground response of the ESP site to the hard rock input SSE motion. Figure 2.5.2-5 shows the transfer function for the ESP site. For some of the lower frequencies (0.1 to 2 Hz), the ESP site slightly de-amplifies the hard rock input ground motion, but for intermediate and high frequencies (2 to 100 Hz), the ESP site amplifies the input ground motion by as much as 1.664 at 20 Hz.

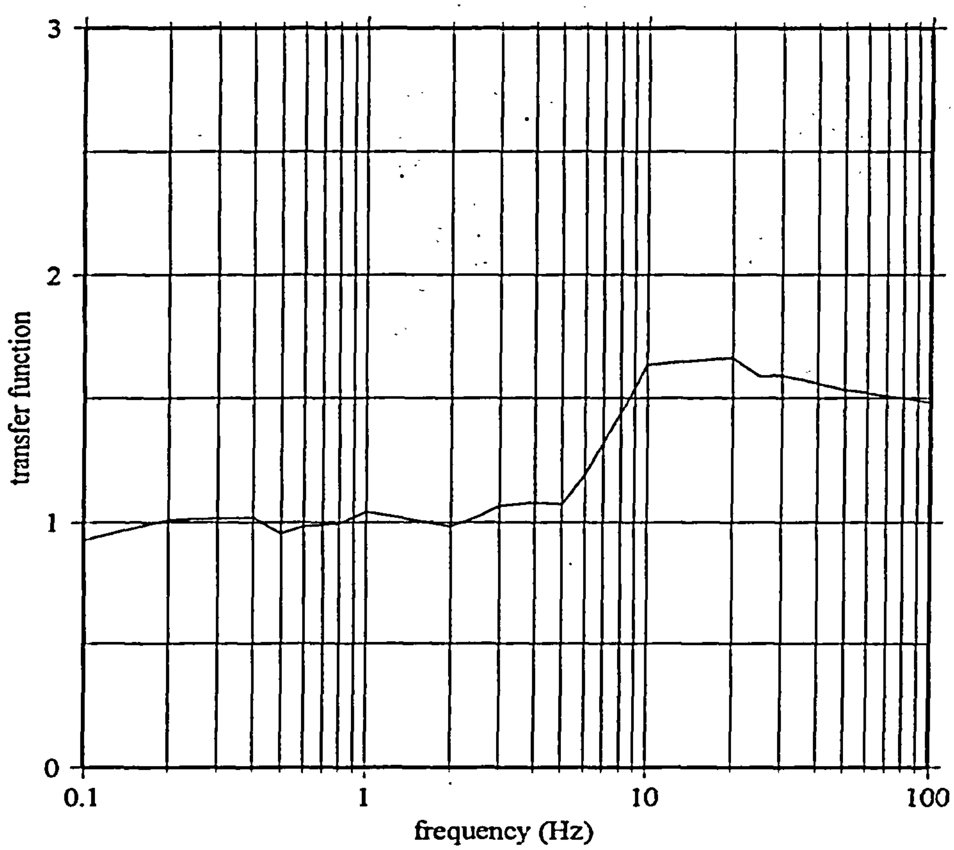


Figure 2.5.2-5 Transfer Function for ESP Site

Development of Vertical SSE Spectrum

To determine the vertical SSE spectrum, the applicant used the vertical-to-horizontal (V/H) response spectral ratios provided in NUREG/CR-6728. The vertical SSE spectrum is given by multiplying the horizontal SSE spectrum by the V/H ratios. The V/H ratios given in NUREG/CR-6728 are for generic CEUS hard rock conditions and depend on the PGA value of the horizontal SSE spectrum. For the ESP site, the V/H ratios used by the applicant are based on having a PGA between 0.2g and 0.5g. However, after incorporating the local ESP site properties to determine the final horizontal SSE spectrum (see Open Item 2.5-2), the applicant's horizontal SSE PGA value increased from 0.37g to 0.55g. Rather than using the V/H ratios given in NUREG/CR-6728 for a PGA greater than 0.5g, the applicant performed a site-specific analysis to confirm the appropriateness of the V/H ratios for a PGA between 0.2g and 0.5g. Figure 2.5.2-6, reproduced from SSAR Figure 2.5-48A, shows the final horizontal and vertical SSE ground response spectrum at the control point at the top of Zone III-IV rock.

For its analysis to confirm the NUREG/CR-6728 V/H ratios for a PGA between 0.2g and 0.5g, the applicant used site-specific shear and compressional wave profile data together with four different earthquake magnitude-distance pairs from the high-frequency (5 and 10 Hz) deaggregation. The applicant computed horizontal and vertical ground motion spectra for each of the magnitude-distance values. In addition, the applicant used site-specific data from its ESP explorations as well as older data from Dominion's site explorations for Units 1 and 2 to develop two velocity profile models. The applicant assigned weights of 0.75 and 0.25 to these two models, with the higher weight for the more recent ESP site investigation model. The applicant stated that the V/H ratios that it obtained from the site-specific analysis are about 30% lower than the V/H ratios provided in NUREG/CR-6728 for a PGA between 0.2g and 0.5g. As such, the applicant concluded that these V/H ratios (see SSAR Table 2.5-27A) are appropriate for the North Anna ESP site. Higher V/H ratios result in a higher vertical SSE spectrum. The V/H ratios used by the applicant range from 0.75 at low frequencies to 1.12 at 50 Hz.

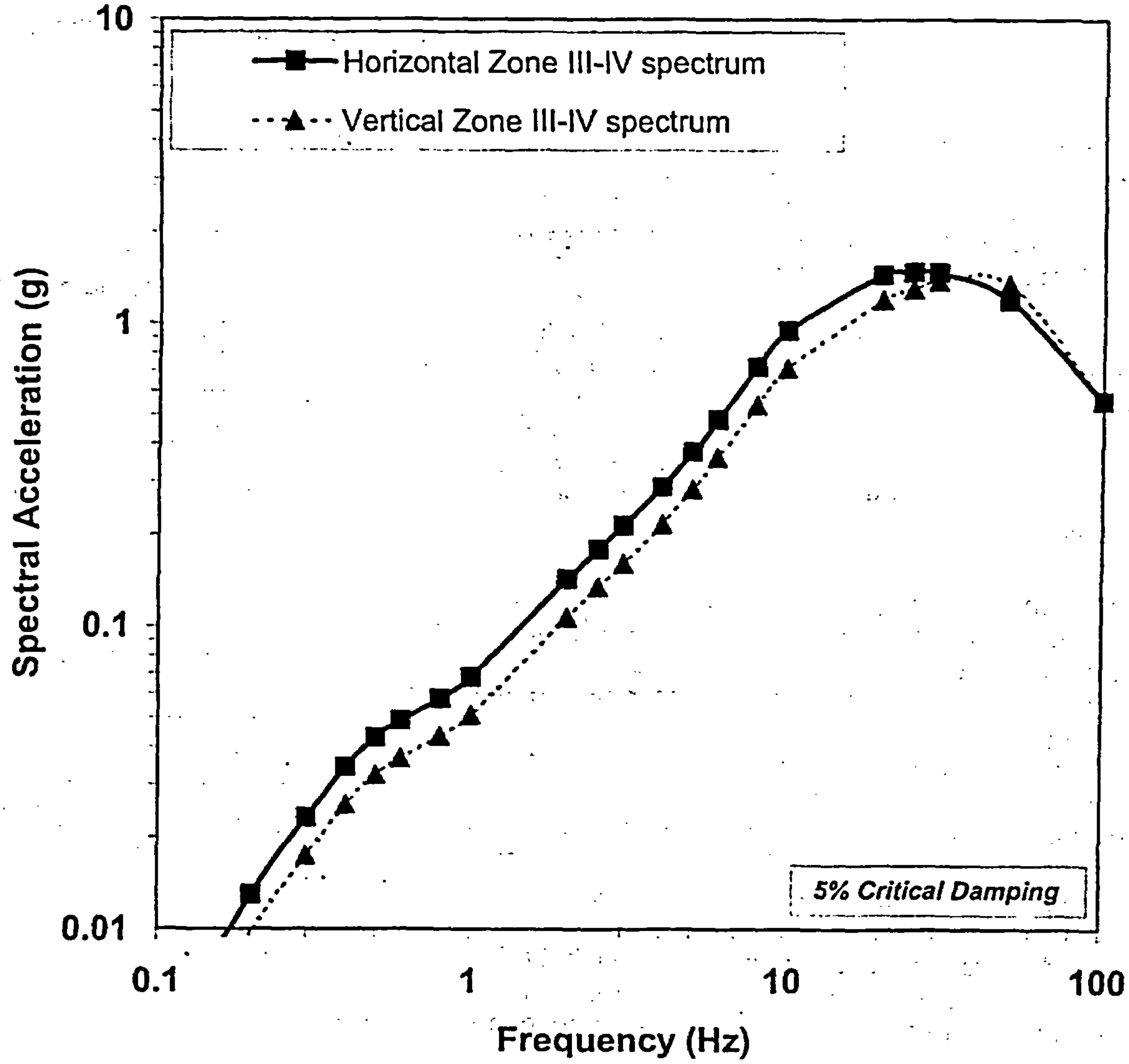


Figure 2.5.2-6 (SSAR Figure 2.5-48A) Selected Horizontal and Vertical Response Spectra for the Hypothetical Rock Outcrop Control Point SSE at the Top of Zone III-IV Material

Sensitivity Studies

The applicant performed two sensitivity studies to demonstrate the appropriateness of the final SSE shown in Figure 2.5.2-6.

The first sensitivity study uses a higher minimum magnitude value for each of the seismic source zones. Currently, the EPRI and LLNL studies use an m_b of 5.0 as the minimum magnitude for calculations, which corresponds to an M_w of 4.6. SSAR Section 2.5.2.6.8 states that there is "abundant evidence that earthquakes with M_w less than 5 do not cause damage to nuclear plant structures and equipment." An M_w of 5 corresponds to an m_b of 5.4. As such, the applicant reran the PSHA with the lower bound magnitude, m_b, set to 5.4. SSAR Table 2.5-28 shows the lower mean 5×10^{-5} spectral accelerations resulting from a higher minimum magnitude value. The lower frequency ground motion is similar to the recommended ground motion spectrum. However, the higher frequency ground motion (i.e., 10 Hz and above) is as much as 20 percent lower than the motion at the same frequency for the performance-based spectrum derived from using a higher minimum magnitude value. The applicant stated that this result demonstrates that the recommended ground motion spectrum incorporates substantial conservatism.

For the second sensitivity study, the applicant revised the uncertainty for the base-case ground motion model to match the uncertainty values of California ground motion models. The uncertainty for CEUS ground motion models, especially for higher frequencies (i.e., 5 Hz and above), exceeds the uncertainty reported for ground motion models based on California strong-motion data. This uncertainty, referred to as aleatory uncertainty, represents the scatter of the observed ground motion about the predicted ground motion. SSAR Section 2.5.2.6.8 states that "it is not obvious that aleatory uncertainties should be higher for ground motions in the eastern U.S. than in California." Using lower aleatory uncertainty, the applicant reran the PSHA and compared the recommended ground motion spectrum to that obtained by using the lower uncertainty. SSAR Table 2.5-28 shows the resulting ground motion spectrum using the lower aleatory uncertainty values. A comparison between this ground motion spectrum and the recommended ground motion spectrum shows that a fairly significant decrease (about 10 percent) in the selected spectrum would occur if the lower aleatory ground motion uncertainties were used in place of those reported in the 2003 EPRI ground motion study.

Future Modification of the Selected Spectrum

SSAR Section 2.5.2.6.9 describes potential modifications to the selected SSE ground motion spectrum to account for embedment and structure effects. According to the applicant, the COL application would include these modifications. The modifications to the SSE spectrum would account for horizontal and vertical spatial variation and incoherence of the ground motion, as well as scattering effects and soil-structure interaction. Horizontal spatial variation in ground motion is more prominent for structures with large plan dimensions and would reduce the input into the structure at high frequencies. SSAR Section 2.5.2.6.9 states that this occurs because the presence of large structures modifies the ground motion input to the base mat and that the modifications become significant at higher frequencies, especially above 10 Hz. The applicant concluded that the SSE spectrum is "an unrealistic input for analysis and design of structures," and, "in order to obtain a realistic design spectrum, the Engineering Design Spectrum (EDS), factors must be considered that affect the shape of the spectrum experienced by structures with large base mats, such as those typical of nuclear power plants." The applicant referred to this "realistic design spectrum" as an engineering design spectrum (EDS).

2.5.2.1.7 Operating-Basis Earthquake

SSAR Section 2.5.2.7 describes the establishment of the operating-basis earthquake (OBE) ground motion for the ESP site. Rather than performing a detailed analysis, the applicant decided to establish the OBE earthquake spectrum as one-third of the SSE spectrum, in accordance with Appendix S to 10 CFR Part 50.

2.5.2.2 Regulatory Evaluation

SSAR Section 2.5.2 presents the applicant's determination of ground motion at the ESP site from possible earthquakes that might occur in the site region and beyond. In SSAR Section 1.8, the applicant stated that SSAR Section 2.5.2 conforms to the requirements of 10 CFR 50.34, "Contents of Applications; Technical Information," Appendix S to 10 CFR Part 50, and 10 CFR 100.23. The applicant further stated in Section 1.8 that it developed this information in accordance with the guidance presented in NUREG-0800, Revision 3, Section 2.5.2; RGs 1.70 and 1.165; and DG-1105, "Site Investigations for Foundations of Nuclear Power Plants." (RG 1.198, of the same title, issued November 2003, superseded DG-1105 since the applicant submitted the SSAR.).

In its review of the application, the staff considered the regulatory requirements of 10 CFR 52.17(a)(1)(vi) and 10 CFR 100.23(c) and (d), which require that the applicant for an ESP describe the seismic and geologic characteristics of the proposed site. In particular, 10 CFR 100.23(c) requires that an ESP applicant investigate the geologic, seismologic, and engineering characteristics of the proposed site and its environs with sufficient scope and detail to support estimates of the SSE ground motion and to permit adequate engineering solutions to actual or potential geologic and seismic effects at the proposed site. In addition, 10 CFR 100.23(d) states that the SSE ground motion for the site is characterized by both horizontal and vertical free-field ground motion response spectra at the free ground surface. Section 2.5.2 of NUREG-0800 provides guidance concerning the evaluation of the proposed SSE ground motion, and RG 1.165 provides guidance regarding the use of PSHA to address the uncertainties inherent in the estimation of ground motion at the ESP site. The staff notes that the application of Appendix S to 10 CFR Part 50 in an ESP review, as referenced in 10 CFR 100.23(d)(1), is limited to defining the minimum SSE for design.

2.5.2.3 Technical Evaluation

This section of the SER provides the staff's evaluation of the seismological, geological, and geotechnical investigations the applicant conducted to determine the SSE ground motion for the ESP site. The technical information presented in SSAR Section 2.5.2 resulted from the applicant's surface and subsurface geological, seismological, and geotechnical investigations performed in progressively greater detail as they moved closer to the ESP site. The SSE is based upon a detailed evaluation of earthquake potential, taking into account regional and local geology, Quaternary tectonics, seismicity, and specific geotechnical characteristics of the site's subsurface materials.

SSAR Section 2.5.2 characterizes the ground motions at the ESP site from possible earthquakes that might occur in the site region and beyond to determine the site SSE spectrum. The SSE represents the design earthquake ground motion at the site and the vibratory ground motion for which certain nuclear power plant SSCs must be designed to remain functional. According to RG 1.165, applicants may develop the vibratory design ground motion for a new nuclear power plant using either the EPRI or LLNL probabilistic seismic hazard analyses for the CEUS. However, RG 1.165 recommends that applicants perform geological, seismological, and geophysical investigations and evaluate any relevant research to determine whether revisions to the EPRI or LLNL PSHA databases are necessary. As a result, the staff focused its review on geologic and seismic data published since the late 1980s that could indicate a need for changes to the EPRI or LLNL PSHAs.

2.5.2.3.1 Seismicity

The staff focused its review of SSAR Section 2.5.2.1 on the adequacy of the applicant's description of the historical record of earthquakes in the region. The historical earthquake catalog used in the original EPRI analysis was complete through 1984. Therefore, in addition to reevaluating the EPRI seismicity catalog, the applicant added seismicity data for the time period from 1985 through 2001.

The staff reviewed both the original EPRI seismicity catalog and the update to the catalog. The applicant added 30 more earthquakes to the regional catalog for the ESP site. Figure 2.5.2-7 depicts the earthquake epicenters in the region surrounding the ESP site. The more recent events since 1984 are shown as solid dots. The cluster of seismicity to the south-southwest of the ESP site is from the CVSZ.

Because the applicant used the EPRI seismicity catalog, which is part of the 1989 EPRI seismic hazard study that the NRC endorsed, the staff concludes that the seismicity catalog used by the applicant is complete and accurate through 1984. The staff compared the applicant's update of the regional seismicity catalog with its own listing of recent earthquakes and did not identify any significant omissions. Accordingly, the staff concludes that the applicant accurately updated the regional seismicity.

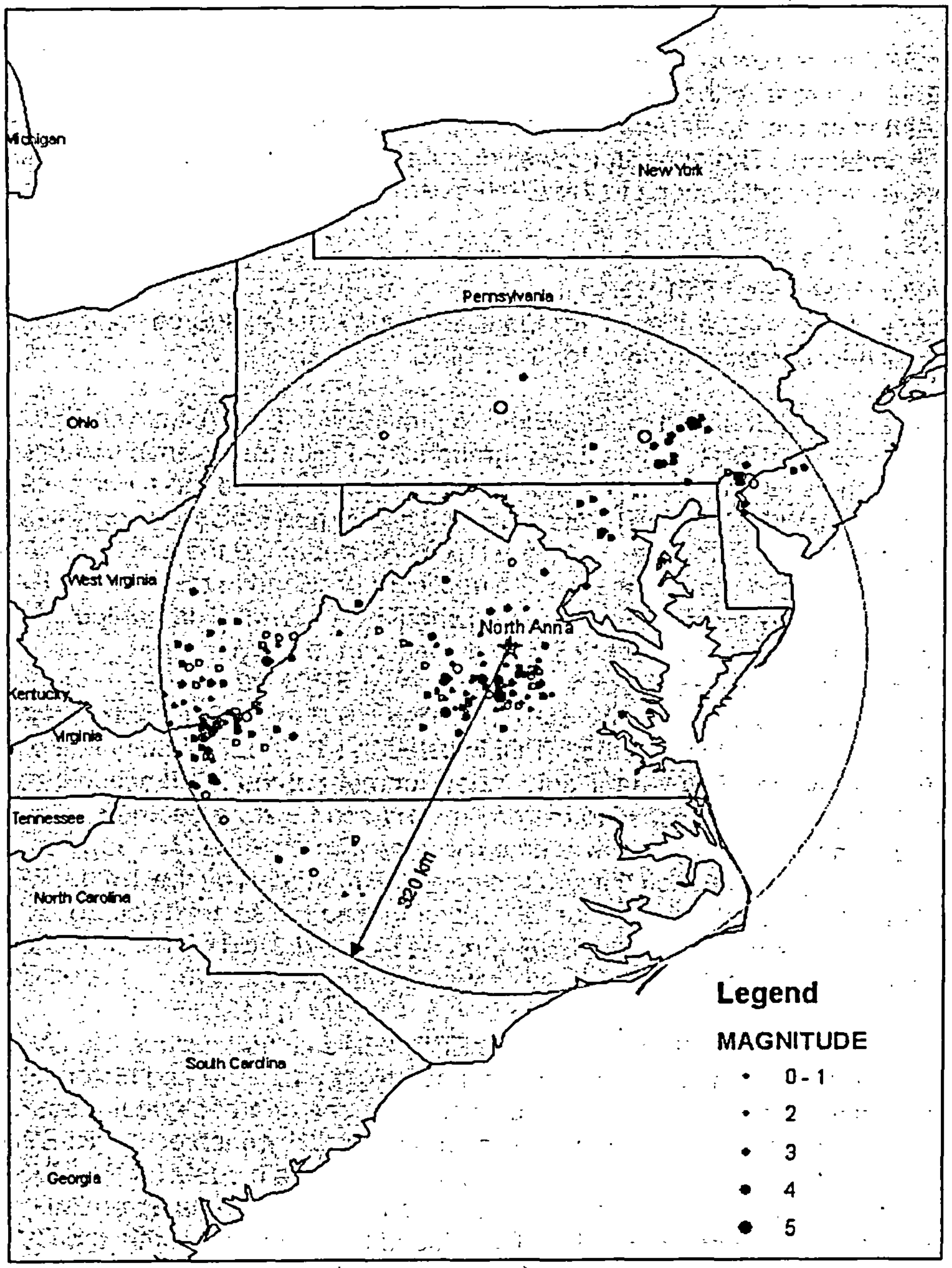


Figure 2.5.2-7 Regional seismicity for ESP site

2.5.2.3.2 Geologic and Tectonic Characteristics of the Site and Region

The staff focused its review of SSAR Section 2.5.2.2 on the applicant's characterization of potential seismic sources in the region surrounding the ESP site. The applicant evaluated recently published studies to determine if the seismic source models used for the 1989 EPRI study needed updating. The applicant concluded that no new information would suggest potentially significant modifications to the EPRI seismic source model, with the following three exceptions:

(1) the newly postulated ECFS
(2) the smaller recurrence interval for the Charleston seismic source zone
(3) the smaller recurrence interval for the NMSZ

In RAI 2.5.2-4(a), the staff asked the applicant to provide additional seismicity parameters beyond those shown in SSAR Tables 2.5-5 through 2.5-11 for the seismic sources surrounding the ESP site. In response to RAI 2.5.2-4(a), the applicant provided the recurrence parameters ("a" and "b" values) used in the EPRI study for the latitude and longitude degree cell encompassing the ESP site region. Because RG 1.165 endorsed the EPRI PSHA methodology and results, the staff used the information the applicant provided in response to RAI 2.5.2-4(a) to determine if any of the seismicity parameters should be updated. In particular, the staff asked the applicant in RAI 2.5.2-4(b) to justify its decision to not update M_{max} values assigned to the CVSZ by the 1989 EPRI ESTs considering the 1994 EPRI study, "Seismotectonic Interpretation and Conclusion from the Stable Continental Region Database." In its response to RAI 2.5.2-4(b), the applicant stated that EPRI initiated the 1994 EPRI study in the mid-1980s specifically for use by the EPRI teams in their development of the EPRI seismic source model. Each of the EPRI teams had access to the preliminary source zone geometry drawn from the 1994 EPRI study in their 1989 seismic source models. Because the M_{max} values used by the EPRI teams generally encompass the M_{max} values recommended by the 1994 EPRI study, the staff concludes that the applicant adequately characterized the seismic source zones, particularly the CVSZ, surrounding the ESP site. Section 2.5.2.1.6 of this SER summarizes the applicant's revisions to SSAR Section 2.5.2 resulting from RAI 2.5.2-4.

In RAI 2.5.2-7, the staff noted that some of the EPRI ESTs did not include the CVSZ as a specific source and asked the applicant to describe how the modern and historical seismicity of the CVSZ is distributed among either a specific source zone or a background source zone. In its response, the applicant described the source model used by each of the six EPRI teams to characterize the CVSZ. The staff reviewed each of the source models for the CVSZ that the applicant provided in its response to ensure that it had adequately characterized the seismic activity of the CVSZ. Each of the EPRI ESTs included the seismicity within the CVSZ as either a specific seismic source zone or as part of a background seismic source zone, and the staff concludes that these source models are acceptable in this respect.

Based on its review of SSAR Section 2.5.2.2 and the applicant's responses to the RAIs, as set forth above, the staff concludes that the applicant adequately investigated and characterized the regional seismic sources. The staff concludes that the 1989 EPRI seismic source models, with the exceptions noted above, remain valid for the ESP site. In addition, the staff concludes that the applicant identified those source zones that may warrant updating based on the results of its sensitivity studies which are presented in SSAR Section 2.5.2.6.

2.5.2.3.3 Correlation of Earthquake Activity with Seismic Sources

The staff focused its review of SSAR Section 2.5.2 on the applicant's efforts to correlate seismicity with known geologic features. Based on a comparison of the updated earthquake catalog to the EPRI catalog, the applicant concluded that none of the earthquakes within the site region can be associated with a known geologic structure. In addition, the applicant concluded that the updated catalog does not show a unique cluster of seismicity that would suggest a new seismic source outside of the EPRI seismic source model. Since the seismicity in the region surrounding the ESP site (see SSAR Figure 2.5-2) is not narrowly focused along any known faults or fault zones, the applicant used areal seismic source zones to characterize the seismic hazard for the ESP site. EPRI teams developed these areal source zones in the mid-1980s.

The staff compared the applicant's seismicity maps with its own and concludes that the applicant has adequately investigated the correlation of earthquake activity with known geologic sources. In particular, the staff plotted the epicenters of the most recent earthquakes surrounding the site (see SER Figure 2.5.2-4) and concurs with the applicant's conclusion that there are no new seismic sources that were not included in the 1989 EPRI seismic source model.

2.5.2.3.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes

To evaluate the applicant's PSHA and controlling earthquakes, the staff reviewed the information presented in SSAR Sections 2.5.2.4 and 2.5.2.6. In SSAR Section 2.5.2.4, the applicant reproduced the 1989 EPRI PSHA using the 1989 seismic sources, 1989 ground motion models, and current PSHA computer program. The applicant concluded that its current PSHA computer program accurately models the 1989 EPRI results for the ESP site location.

For its PSHA, the applicant considered (1) a new regional earthquake catalog, (2) new M_{max} information, (3) new seismic source characterizations, and (4) new ground motion models. Based on PSHA sensitivity studies, which incorporate each of these four items, the applicant concluded that the more recent characterization of the Charleston seismic source recurrence interval and the new ground motion models result in significant changes to the PSHA for the ESP site.

For Revision 3 (September 2004) of Section 2.5.2 of the SSAR, the applicant repeated its deaggregation of the PSHA results to determine the controlling earthquake magnitudes and distances. Although the applicant used the same reference probability (mean 5×10^{-5}), the most recent deaggregation uses the mean PSHA hazard results rather than the median hazard results to calculate the controlling earthquakes. Because the mean hazard curves are higher than the median curves, the applicant's use of the mean curves is conservative.

In its response to RAI 2.5.2-5, the applicant explained how it incorporated the alternative characterization of the Charleston seismic source into the final PSHA. It stated that the alternative characterization of the Charleston source was evaluated both independently and additively to conservatively assess the maximum possible change to the hazard at the North Anna ESP site from the revision to this postulated source. The revisions to the Charleston source include a shorter recurrence interval (550 years) and different weights for the M_{max} (M_w 6.8 to 7.5). The ECFS-S seismic source was added to the source models for each of the six

EPRI teams for the final PSHA. Because the applicant reduced the recurrence interval, increased the weighting of higher M_{max} values, and also included the alternate source geometry of the ECFS-S into the final PSHA, the staff concludes that the applicant conservatively updated the characterization of the Charleston seismic source. This latter modification is conservative because it amounts to counting the Charleston seismic source twice. The result of these changes to the PSHA is that the low-frequency controlling earthquake for the ESP site has a magnitude of 7.2 at a distance of 308 km.

In RAI 2.5.2-2, the staff asked the applicant to provide additional details on the 2003 EPRI ground motion evaluation that it used for the ESP PSHA. To update the ground motion attenuation models in the CEUS, EPRI sponsored a Senior Seismic Hazard Advisory Committee (SSHAC) Level 3 analysis. NUREG/CR-6372 provides the guidelines for performing such an analysis. The EPRI ground motion study used 13 different ground motion attenuation relationships grouped into four clusters. In RAI 2.5.2-2(c), the staff asked the applicant to provide the weight assigned to each of the 13 ground-motion relationships within their respective cluster. For cluster 1, EPRI gave the highest weight (0.90) to the three attenuation relationships reported by Silva et al. The staff inferred from this higher weight that these relationships must have fit the data much better than other relationships. However, the applicant did not provide plots or tables of the residuals as a function of attenuation relation, magnitude, distance, and frequency. Therefore, the staff was unable to evaluate the weighting EPRI selected for cluster 1. Similarly, for clusters 2 and 3, the ground motion experts applied higher weights to different attenuation relationships within each cluster. Neither the EPRI 2003 ground motion report nor the applicant's response to RAI 2.5.2-2 provides the rationale for these weights.

In RAI 2.5.2-2(b), the staff asked the applicant to provide additional information on the Silva et al. cluster 1 attenuation relationships. In response, the applicant provided additional documentation on these attenuation relationships. The Silva et al. cluster 1 relationships use an expression for the seismic attenuation parameter, Q, that is frequency dependent. This frequency-dependent Q value was derived from an inversion of the data from the 1988 Saguenay earthquake. This inversion solves for Q, as well as the local site attenuation parameter kappa and the stress drop, which is the difference between the initial stress before and earthquake and the final stress. The staff was unable to determine how the recordings from a single earthquake can provide well-resolved values of both crustal Q and site kappa. In addition, the Q value of 317 at 1 Hz is much lower than values found in other studies of eastern North American earthquakes. In addition, other studies have found less frequency dependence of Q in the east than in the west, which is contrary to the findings of Silva et al.

In RAI 2.5.2-2(d), the staff asked the applicant to explain the weights given to each of the four clusters. In response to RAI 2.5.2-2, the applicant stated that the expert panel members, convened for the EPRI ground motion study, were asked to subjectively evaluate how well the alternative ground motion models relied on seismological principles. The staff considers the applicant's response to RAI 2.5.2-2(d) to be somewhat indirect. The applicant provided additional information, but the details still remain abstract in terms of specific "seismological principles." The response emphasizes the ranking of model clusters and the judgments involved in balancing data consistency and adherence to seismological principles. However, the applicant provided only abstract and very general references to these seismological principles. As a result, the staff was unable to evaluate the criteria or the weights applied to the four clusters.

In Open Item 2.5-1, the staff requested clarification and further information from the applicant regarding each of the three issues outlined above. With regard to the unequal weighting for the cluster 1 attenuation relationships (RAI 2.5.2-2(a)), the applicant provided the staff with tables of statistics that compare each of the ground motion relationships and the CEUS earthquake database. For each model and ground motion frequency, the applicant determined the deviation between the median model prediction and the actual recorded motion. Using the mean and variance of the deviations, the applicant determined the weight for each model in cluster 1. In addition to the tables of statistics, the applicant also provided plots of residuals for each of the cluster 1 ground motion models and plots comparing the final overall cluster 1 model to the actual CEUS earthquake data.

With regard to the staff's concerns, described above in RAI 2.5.2-2(b), concerning the Silva et al. cluster 1 attenuation relationships, the applicant stated the following:

> The model functional form, basis for parameter selection, and the results developed in Silva et al. (2002) and its predecessor, Silva et al. (1997), are the responsibility of the lead author. Of particular relevance is the interdependence between model parameters, how the parameters were determined, model sensitivity to its parameters, and reasonable ranges in parameter values, based on expert judgement and expert interpretation of the scientific literature. It is unclear if a summary justification for the results of the Silva et al. (1997 and 2002) studies would resolve the items identified that seem, ultimately, to represent differences in expert judgement.
>
> Differences in expert judgement are often difficult to reconcile. For this very reason, the SSHAC [Senior Seismic Hazard Advisory Committee] process was developed and accepted for use by the NRC. The EPRI 2003 ground motion model was developed by implementing a SSHAC Level 3 assessment process during which the EPRI Expert Panel identified the Silva et al. relationships as ones that should be included in the assessment and evaluated. The EPRI Expert Panel considered specific parameterizations of individual ground motion relationships in determining whether or not a relationship should be included in the SSHAC Level 3 assessment process. All ground motion relationships identified as viable by the Expert Panel were evaluated using the same criteria following the SSHAC Level 3 process.
>
> The SSHAC process does not guarantee that every scientist will agree with the assessments. It is rather intended to assure that the assessed results reflect the preponderance of current scientific views, which is the underpinning of safety decisionmaking.

Since the EPRI 2003 expert panel members gave the three Silva et al. attenuation relationships the highest overall weight (0.90) in cluster 1, the staff asked the applicant to explain whether this biased the final overall cluster 1 ground motion model towards the model functional form and parameters used by these three attenuation relationships. Specifically, the three Silva et al. attenuation relationships each have different earthquake source terms and parameters; however, these relationships have the same wave propagation travel path terms and parameters. As such, the staff asked the applicant to explain if this limited path variability biased the overall cluster 1 ground motion model. In response to the staff's concern, the applicant stated the following:

> The ground motion models in Cluster 1 considered a range of alternative stress drop models and alternative Q and path models. Collectively, these models represent alternative single-corner [shape] source spectrum models for the CEUS. In aggregate, these models provide a measure of the epistemic [modeling] uncertainty in the median ground motion based on the single-corner source spectrum models (e.g., intra-cluster variability).

The applicant also stated that, as part of the CEUS model development, EPRI evaluated whether an additional component of uncertainty for wave propagation travel path effects should be included for each of the model clusters. The individual models within each model cluster contribute to the overall cluster variability since they each use different source and path parameters. However, the EPRI (2004) report states that there may be additional variability in the modeling parameters that is not captured by the ground motion models that make up a cluster. As described above, the staff expressed concern that the path variability for cluster 1 may be too small since the three Silva et al. attenuation relationships, which have an overall weight of 0.90, each have the same travel path model terms and parameters. EPRI, as part of its ground motion assessment, compared the overall cluster 1 ground motion variability (both source and path) with the variability of different path model terms and parameters used by the different individual models. In other words, EPRI isolated the travel path variability by equally weighting each of the alternative travel path models and compared this variability to the overall variability for each of the ground motion clusters. Figure 4-6 of the EPRI (2004) ground motion report shows this travel path variability, and Figure 4-2 of the report depicts the cluster 1 variability. Comparing the variability shown in Figures 4-2 and 4-6, the applicant concluded that "these variabilities were similar, although the results in Figure 4-6 are higher, particularly at distances beyond 100 km." The applicant stated that most of the models in cluster 1 had already "considered the variability in path effects as aleatory [e.g., random scatter] variability and thus it is ultimately included in the overall probabilistic hazard analysis."

With regard to the staff's concerns, described above in RAI 2.5.2-2(d), the latest version of the EPRI ground motion report provides an expanded explanation of the seismological principles that the expert panel members used to determine the overall weight for each of the four clusters. The seismological principles considered by the expert panel members include (1) seismic source modeling, (2) crustal wave propagation, and (3) near-surface crustal effects. Based on the single criterion of seismological principles, the four ground motion clusters were weighted fairly equally (0.245, 0.221, 0.257, and 0.277). In addition to seismological principles, the expert panel members also relied on consistency with the CEUS earthquake database and the modeling of variability as criteria for determining the final overall cluster weights (0.275, 0.312, 0.196, and 0.217).

For its review of the applicant's response to Open Item 2.5-1, the staff examined the plots and tables of model residuals provided by the applicant for the cluster 1 ground motion models. The staff verified that, for the ground motion frequencies (1, 5, and 10 Hz), the three Silva et al. ground motion models do provide the smallest mean residual values (i.e., best fit to the earthquake data) compared to the other cluster 1 models. As a result, EPRI gave weights of 0.192, 0.148, and 0.560 to these three ground motion models.

To resolve the concern that these three models, which account for 90 percent of the overall cluster 1 model, do not adequately represent the variability in travel path, the staff compared Figures 4-2 and 4-6 in the EPRI (2004) ground motion report. As noted by the applicant, there is a slightly higher variability for distances beyond 100 km as shown in Figure 4-6. This result suggests that travel path variability for the overall cluster 1 model may be somewhat low. However, for source distances out to about 300 km, the differences in variability are negligible. This result implies that the overall cluster 1 model uncertainty contains a sufficient amount of travel path variability.

To resolve the concern regarding the use and application of seismological principles to assign final overall weights to each of the four cluster groups, the staff reviewed the new information provided in the latest version of the EPRI ground motion report. Based on the criterion of seismological principles, the EPRI expert panel members gave similar weights to each of the four ground motion clusters. This result implies that the EPRI expert panel members did not find significant differences among the four model clusters regarding the use of seismological principles. The staff also reviewed the seismological principles used by the expert panel members and determined that these principles are relevant and significant for ground motion estimation.

In conclusion, as described above, the applicant has adequately resolved each of the staff's concerns with regard to the development by EPRI of new ground motion models for the CEUS. Therefore, the staff concludes that the applicant's use of the EPRI (2004) ground motion attenuation models provides an adequate estimate of the ground motion for CEUS earthquakes and, as such, an adequate characterization of the seismic hazard for the ESP site.

The staff concludes that the applicant's PSHA adequately characterized the overall seismic hazard of the ESP site. As set forth above, the staff finds that the applicant's underlying assumptions and update of the previous EPRI PSHA adequately incorporate the most recent studies and evaluations of the seismic source zones surrounding the ESP site. The staff also concludes that the applicant's controlling earthquakes for the ESP site (magnitude of 5.4 at 20 km and magnitude of 7.2 at 308 km) are generally consistent with previous PSHA results for the region. In addition, the staff finds that the ground motions developed by the applicant from the controlling earthquakes are consistent with the most recent ground motion evaluations. Accordingly, the staff concludes that the applicant followed the guidance in RG 1.165 for evaluating the regional earthquake potential and determining the ground motion resulting from the controlling earthquakes. Based on the foregoing, the staff considers Open Item 2.5-1 to be resolved.

2.5.2.3.5 Seismic Wave Transmission Characteristics of the Site

The staff focused its review of SSAR Section 2.5.2.5 on the applicant's incorporation of the seismic wave transmission characteristics of the material overlying the base rock at the site into the determination of the SSE. SSAR Section 2.5.4.7 provides a description of the transmission characteristics of the site material.

In RAIs 2.5.2-1(c) and 2.5.2-8, the staff asked the applicant to explain how it factored the properties of the site-specific subsurface materials into the determination of the SSE. According to the applicant's responses, it calculated the SSE directly using the EPRI 2003 ground motion models, which assume generic hard rock conditions for all of the CEUS. The shear wave velocity assumed by the EPRI 2003 ground motion models for the generic hard rock conditions is 9200 ft/s. The applicant stated that, since the containment (reactor) building and primary supporting safety-related structures would be founded on sound bedrock, either Zone IV or Zone III-IV rock, the generic hard rock conditions assumed by the EPRI 2003 ground motion report are a "good approximation" for the ESP site. As such, the applicant did not factor in any of the local ESP site properties for its determination of the SSE.

As set forth in the DSER, the staff considered the applicant's response above to be inadequate based on a comparison of the average bedrock Zone III-IV shear wave velocity (3300 ft/s) and the generic hard rock shear wave velocity (9200 ft/s) assumed by EPRI 2003. SSAR Figure 2.5-62 shows that the measured shear wave velocity values for the upper soil and rock layers beneath the ESP site are below that of the hard rock conditions assumed by EPRI 2003. Thus, the hard rock shear wave velocity of 9200 ft/s may not be reached at the ESP site until a considerable depth below the ground surface. In addition, 10 CFR 100.23(d)(1) states the following:

> The Safe Shutdown Earthquake Ground Motion for the site is characterized by both horizontal and vertical free-field ground motion response spectra at the free ground surface.

Therefore, as further set forth in the DSER, the staff determined that the applicant's SSE did not represent the free-field ground motion at the free ground surface. Open Item 2.5-2 covered the necessity to include the local ESP site conditions into the determination of the SSE.

In response to Open Item 2.5-2, the applicant reran its analysis to determine the response of the ESP site at the free ground surface, as required by 10 CFR 100.23(d)(1). The applicant's new analysis use a rock subsurface profile that extends from the top of Zone III-IV bedrock to a depth of 160 ft under the site where the shear wave velocity reaches about 9200 ft/s. The applicant defined the top of rock layer Zone III-IV to be its control point for consistency with the guidance in Section 3.7.1 of NUREG-0800, which states the following:

> For sites composed of one or more thin soil layers overlying a competent material or in case of insufficient recorded ground-motion data, the control point is specified on an outcrop or a hypothetical outcrop at a location on the top of the competent material.

The applicant used the ESP rock subsurface profile to estimate the ground motion amplification of the site and, therefore, to determine an SSE that incorporates the local site rock properties. To determine the control point SSE at the top of Zone III-IV rock, the applicant (1) developed a shear wave velocity profile for the ESP site, (2) generated alternative randomized rock columns to incorporate the variability in the rock properties, (3) selected seed earthquake time histories, and (4) performed the final ground response analysis. SER Section 2.5.2.1.6 describes each of these steps in detail.

The staff reviewed the applicant's analysis to ensure that it accurately incorporates the local site properties and conditions as well as their uncertainties. The applicant developed 50 different randomized rock columns in order to model the uncertainties in the rock properties, such as shear wave velocities, densities, and damping values. The staff also verified that the response spectra from the two earthquake time histories used by the applicant for its convolution match the low- and high-frequency spectra from the two controlling earthquakes. As a result of the applicant's inclusion of the local site rock properties, some of the spectral acceleration values for the final SSE ground motion spectrum increased by as much as a factor of 1.67. As shown previously in Figure 2.5.2-6, these increases mainly occur at frequencies above 10 Hz. The staff concludes that the applicant's site response analysis accurately incorporates the local site properties as well as the variability in these properties. Based on the above, the staff considers Open Item 2.5-2 to be resolved.

2.5.2.3.6 Safe-Shutdown Earthquake Ground Motion

The staff focused its review of SSAR Section 2.5.2.5 on the applicant's procedure to determine the SSE. For SSAR Revision 3, issued in September 2004, the applicant used two different methods to determine the ground motion response spectra for the ESP site.

Originally, the applicant used a new method to determine the site SSE, referred to as a performance-based approach. In RAI 2.5.2-1, the staff asked the applicant to explain how the performance-based approach meets the requirements of 10 CFR 100.23, which provide the geologic and seismic siting criteria as well as a definition of the SSE. In response to RAI 2.5.2-1, the applicant explained how the performance-based approach conforms with the requirements of 10 CFR 100.23. In RAI 2.5.2-9, the staff asked the applicant for further details on the performance-based approach beyond those provided in SSAR Section 2.5.2.6. In response to RAI 2.5.2-9, the applicant provided further justification for the performance-based approach, including the derivation of some of the key relationships.

After reviewing the applicant's responses to RAIs 2.5.2-1 and 2.5.2-9 regarding its performance-based approach, the staff informed the applicant that it would need to devote additional time and resources to review this new method. In a letter dated August 19, 2004, the applicant informed the staff that it would revise SSAR Section 2.5.2 to base the selected SSE on the reference probability approach, in accordance with RG 1.165. The applicant also indicated that it would retain the performance-based approach in the SSAR as "alternate and further justification for the final SSE." Since the applicant has chosen to determine the final SSE in accordance with RG 1.165, the staff decided that it will not evaluate the performance-based approach for conformance with the requirements of 10 CFR 100.23 or review the overall acceptability of the approach. Therefore, the staff did not reach any conclusion with respect to the information in the SSAR regarding the performance-based approach or the applicant's responses to RAIs 2.5.2-1 and 2.5.2-9 that pertain to the performance-based approach.

In conjunction with its decision to base the final SSE on the reference probability approach in accordance with RG 1.165, the applicant also decided to use a higher reference probability (5×10^{-5}) than that recommended by RG 1.165 (1×10^{-5}). In addition, the applicant chose to use the mean PSHA curves rather than the median curves. Because the mean hazard curves are higher then the median curves, the applicant's use of the mean curves is conservative. In RAI 2.5.2-1(d), the staff asked the applicant to justify the proposed higher reference probability. In response to RAI 2.5.2-1(d), the applicant stated that it used a higher reference probability because of (1) higher ground motion estimates from the 2003 EPRI ground motion models, (2) shorter recurrence intervals for the New Madrid and Charleston seismic sources, and (3) the use of the mean hazard instead of the median hazard. Each of these factors (particularly the first two) increase the overall seismic hazard level for the CEUS and specifically, for the 29 nuclear power plant sites used to determine the original reference probability. Because the reference probability recommended in RG 1.165 ($1x10^{-5}$) is based on the LLNL and EPRI PSHAs from the late 1980s, the staff concurs with the applicant's conclusion that this value is likely to be out of date and overly conservative.

To evaluate the applicant's use of a higher reference probability ($5x10^{-5}$) and use of mean rather than median PSHA results, the staff performed an independent analysis to reevaluate the reference probabilities for the 29 nuclear power sites in the CEUS that were used to determine the original reference probability. For its independent analysis, the staff used the most recent 2002 USGS PSHA mean and median hazard curves to determine the probability of exceeding the SSEs for the 29 CEUS sites. The staff also applied the same 5 Hz and 10 Hz site correction factors that were used in the LLNL seismic hazard analysis, published in 1993. Although the staff has not officially endorsed the 2002 USGS PSHA results, the staff was able to verify that the reference probability proposed by the applicant ($5x10^{-5}$) is sufficiently conservative. This larger reference probability value ($5x10^{-5}$) implies a lower return period (20,000 yrs) for the design ground motion; however, the staff was able to verify through its analysis that this revised reference probability results in a final SSE of adequate severity that is representative of the seismic hazard for the ESP site.

Using the RG 1.165 approach, the applicant determined the ground motion response spectra for the ESP site controlling earthquakes (magnitude of 5.4 at 20 km and magnitude of 7.2 at 308 km). The applicant then enveloped these two response spectra with the performance-based spectrum to create the final SSE spectrum. The staff's acceptance of the use of the performance-based spectrum to envelope the two controlling earthquake response spectra does not imply that the staff has endorsed the performance-based approach. As described in Appendix F to RG 1.165, any smooth spectral shape that envelopes the two controlling earthquake response spectra is acceptable as the site SSE. However, as set forth in the DSER, the staff (see Open Item 2.5-2) determined that this final SSE did not meet the requirements specified in 10 CFR 100.23(d)(1), which states that "the Safe Shutdown Earthquake Ground Motion for the site is characterized by both horizontal and vertical free-field ground motion response spectra at the free ground surface." As discussed above, the applicant addressed the staff's concern by performing a detailed site response analysis that incorporates the local site properties as well as the variability in these properties. Therefore, the final ESP site SSE meets the requirements specified in 10 CFR 100.23 in that it incorporates the local site subsurface properties and represents the free-field ground motion.

To determine the vertical SSE spectrum, the applicant used the V/H response spectral ratios provided in NUREG/CR-6728. To confirm the appropriateness of these V/H ratios, the applicant performed a site-specific analysis. For the site-specific analysis, the applicant used the ESP site compressional and shear wave profile data together with four different earthquake magnitude-distance pairs to compute vertical and horizontal ground motion spectra for the Zone III-IV hypothetical rock outcrop control point. The applicant stated that the V/H ratios that it obtained from the site-specific analysis are about 30% lower than the V/H ratios provided in NUREG/CR-6728 for a PGA between 0.2g and 0.5g. As such, the applicant concluded that these V/H ratios are appropriate from the North Anna ESP site.

To verify the adequacy of the V/H SSE ratios used by the applicant, the staff evaluated the applicant's site specific analysis. For its evaluation, the staff considered the adequacy of the four magnitude-distance pairs and the compressional and shear wave velocity profiles. Regarding the magnitude-distance pairs, four earthquake magnitude-distance pairs used by the applicant range from M = 5.1 to 6.1 with accompanying distances from 7.5 km to 75 km. For comparison, the high-frequency controlling earthquake from the CVSZ for the ESP site is M = 5.4 at 20 km. Accordingly, the staff finds that they adequately represent the range of magnitudes and distances from a local earthquake in the CVSZ. Regarding the compressional and shear wave velocity profiles, the applicant used data from both its ESP site exploration and older data from the licensee's exploration for Units 1 and 2. The applicant formed two velocity models from these two data sets, giving larger weight (75 percent) to the model based on the more recent ESP velocity data. The staff verified that these two models accurately represent the actual site properties given by the compressional and shear wave velocity profiles. The staff then compared the site-specific V/H ratios with the ratios actually used by the applicant from NUREG/CR-6728. On average, the mean V/H ratios from the site-specific analysis are approximately 30 percent lower, over the complete frequency range considered, than the V/H ratios used by the applicant from NUREG/CR-6728 for a PGA between 0.2g and 0.5g. Since the V/H ratios used by the applicant range from 0.75 to greater than 1.0 and these V/H ratios are 30 percent higher than V/H ratios from the site-specific analysis, the staff finds that they are conservative and adequate for the North Anna ESP site.

In SSAR Sections 2.5.2.6.9 and 2.5.2.6.10, the applicant alluded to future modifications of the site SSE spectrum in order to obtain an engineering design spectrum (EDS) that represents "the proper input into the large nuclear power plant structures." The applicant stated that the ESP site SSE is not suitable for the design of the SSCs of nuclear power plants because of high spectral accelerations in the high-frequency range (about 15 to 30 Hz). According to the applicant, the EDS would take into account plant-specific structural characteristics and local site conditions, as well as the ESP SSE spectrum. However, the ESP application does not include the EDS because the applicant has not selected a specific reactor design. The applicant proposed to include the EDS as part of a COL application. Because the applicant did not provide any specific recommendations or procedures for developing the EDS, the staff cannot evaluate the merits of the proposed approach.

The staff considers the SSE developed for the ESP site to be consistent with Appendix S to 10 CFR Part 50, which defines the SSE as the "vibratory ground motion for which certain structures, systems, and components must be designed to remain functional." Section 2.5.2.3.5 of this SER addresses the applicant's compliance with 10 CFR 100.23(d) with regard to the SSE. Future modifications of the SSE spectrum, if any, in an application for a COL or CP must be compatible with 10 CFR Parts 50 and 100.

2.5.2.4 Conclusions

As set forth above, the staff reviewed the seismological information submitted by the applicant in SSAR Section 2.5.2. On the basis of its review of SSAR Section 2.5.2 and the applicant's responses to the RAIs and open items, as described above, the staff finds that the applicant has provided a thorough characterization of the seismic sources surrounding the site, as required by 10 CFR 100.23. In addition, the staff finds that the applicant has adequately addressed the uncertainties inherent in the characterization of these seismic sources through a PSHA, and that this PSHA follows the guidance provided in RG 1.165. The staff concludes that the controlling earthquakes and associated ground motion derived from the applicant's PSHA are consistent with the seismogenic region surrounding the ESP site. In addition, the staff finds that the applicant's SSE was determined in accordance with RG 1.165 and Section 2.5.2 of NUREG-0800 and accurately includes the effects of the local ESP subsurface properties. The staff concludes that the proposed ESP site is acceptable from a geologic and seismologic standpoint and meets the requirements of 10 CFR 100.23.

2.5.3 Surface Faulting

SSAR Section 2.5.3 describes the potential for tectonic fault rupture at the ESP site. The applicant concluded that the site has no potential for tectonic fault rupture since no capable tectonic sources exist within a 5-mile radius of the ESP site. SSAR Section 2.5.3.1 describes the applicant's geological, seismological, and geophysical investigations to assess the potential for surface faulting within a 5-mile radius of the ESP site. SSAR Section 2.5.3.2 describes the geologic evidence, or absence of evidence, for surface deformation. SSAR Section 2.5.3.3 describes the correlation of earthquake epicenters with faults in the vicinity of the ESP site. SSAR Section 2.5.3.4 provides the ages of the most recent deformations in the site area. Finally, SSAR Sections 2.5.3.5 through 2.5.3.8 describe tectonic structures in the site area, the absence of capable sources and Quaternary deformation, and the potential for tectonic or nontectonic deformation at the site.

2.5.3.1 Technical Information in the Application

2.5.3.1.1 Surface Faulting Investigations

<u>Geological, Seismological, and Geophysical Investigations</u>

According to SSAR Section 2.5.3.1, the applicant performed the following investigations to assess the potential for surface faulting at and within a 5-mile radius of the ESP site:

- compilation and review of existing data
- interpretation of aerial photography
- field reconnaissance
- review of seismicity
- discussions with current researchers in the area

Based on previous site investigations performed for the existing NAPS Units 1 and 2, the applicant concluded that (1) no evidence of surface rupture, surface warping, or the offset of geomorphic features indicative of active faulting exists, (2) no historical seismic activity has occurred in the site area, as the closest epicenter location is 30 miles away, and (3) inspections of excavations during construction and examination of soil and rock samples from borings reveal no evidence of geologically recent faulting.

The applicant performed aerial and field reconnaissance investigations within a 25-mile radius of the ESP site, and it examined and interpreted aerial photographs of all known faults within 5 miles of the site. Through these studies, the applicant verified the existence of mapped bedrock faults in the site area and assessed the presence or absence of geomorphic features that indicate potential Quaternary fault activity.

In addition to its own investigations, the applicant used USGS maps of the area, as well as a USGS compilation of all Quaternary faults, liquefaction features, and possible tectonic features in the eastern United States, to assess the potential for surface faulting within a 5-mile radius of the ESP site.

Geologic Evidence for Surface Deformation

SSAR Section 2.5.3.2 lists the following bedrock faults that are within 5 miles of the ESP site:

- Chopawamsic fault
- Spotsylvania thrust fault
- unnamed faults "a," "b," and "c"
- Sturgeon Creek fault
- Long Branch thrust fault

All of these faults formed during the early Paleozoic Era as part of the regional Taconic orogeny and may have become reactivated during later Paleozoic orogenies (Acadian and Allegheny). The applicant stated that several of the faults may have been locally reactivated during the Triassic episode of continental rifting; however, none of these faults border Triassic basins, implying that Triassic reactivation, if any, was not significant. Figure 2.5.3-1, reproduced from SSAR Figure 2.5-56, shows these Paleozoic faults on an ESP site vicinity geologic map.

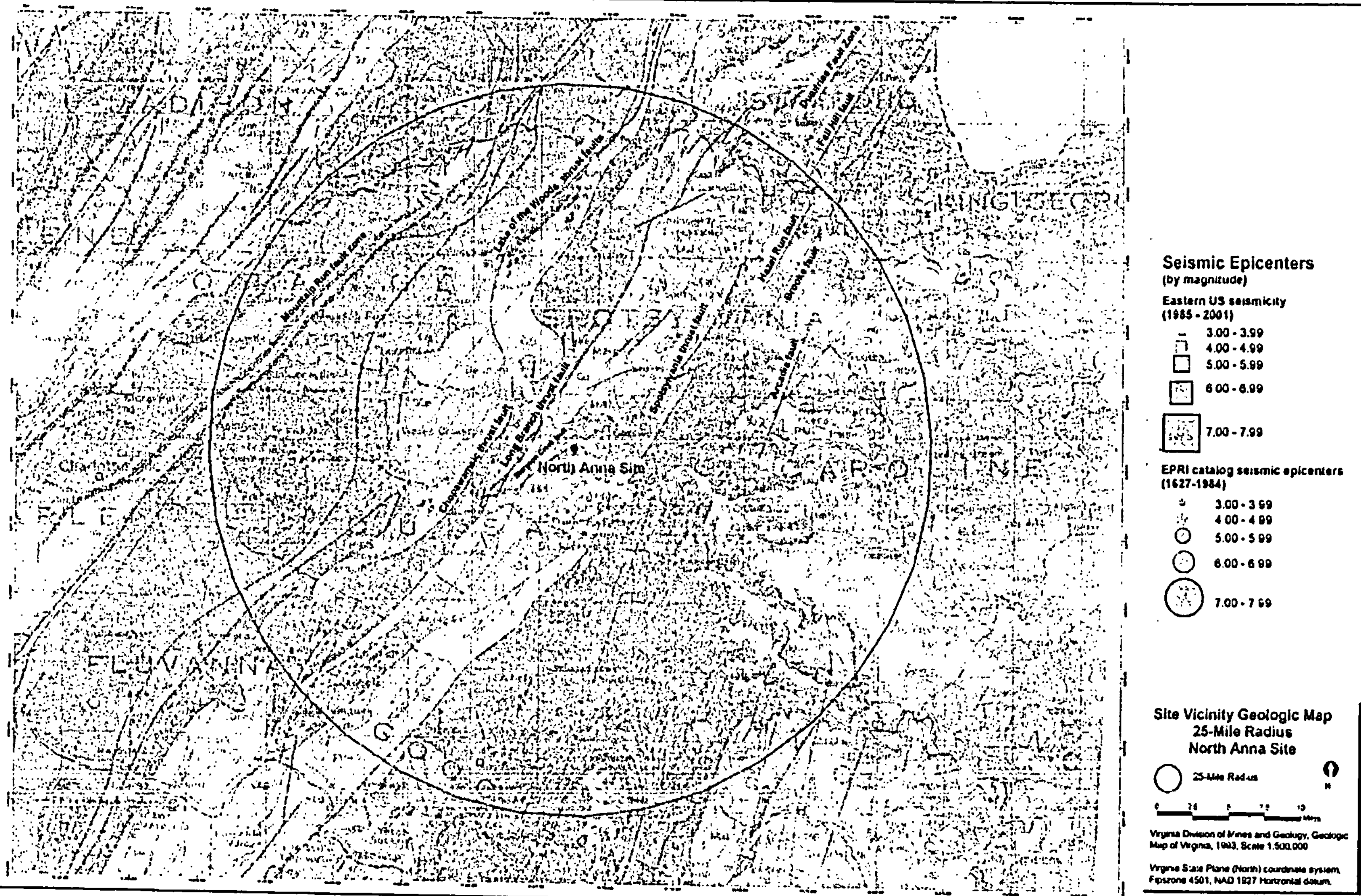


Figure 2.5.3-1 Site vicinity geologic map and seismicity (25-mile radius)

SSAR Section 2.5.3.2 states that the applicant identified no deformation or geomorphic features indicative of potential Quaternary activity in the literature or during aerial and field reconnaissance. In addition, the recent USGS compilation of all Quaternary faults, liquefaction features, and possible tectonic features in the eastern United States includes none of the faults listed above as potential Quaternary faults.

In RAI 2.5.3-1, the staff asked the applicant to provide additional detail on its field investigations and aerial reconnaissance of the site area. In response to RAI 2.5.3-1, the applicant stated that it performed aerial and field reconnaissance along faults within a 5-mile radius of the ESP site. The applicant's reconnaissance emphasized unnamed fault "a" and the Sturgeon Creek fault because of their proximity to the site. In addition, the applicant covered parts of the Spotsylvania, Chopawamsic, and Long Branch faults where these faults were mapped near local roads and/or where they potentially offset plutonic (igneous) margins or metamorphic contacts. Based on the absence of any geomorphic expression indicative of potential Quaternary deformation, the applicant concluded that none of the faults are capable. In addition, the applicant stated that all of the faults in the site area cross gently rolling topography, with relief on the order of 200 ft, and that this rolling topography formed through dissection and erosion of a once broad, continuous Miocene (5-24 ma) pediment that extended across the region. The applicant looked for potential elevation differences in the Miocene pediment gravels across each of the faults that would suggest post-Miocene vertical separation. Based on its field reconnaissance, the applicant did not observe any significant elevation differences. Therefore, the applicant concluded based on its detailed field observations and aerial reconnaissance that, for all seven faults within the site area, no evidence or criteria would suggest Quaternary activity on these structures.

Foundation excavations for the abandoned NAPS Units 3 and 4 exposed the unnamed bedrock fault "a" traversing the North Anna site. Detailed investigations of this fault show no evidence of Quaternary faulting. Therefore, the applicant concluded that this fault is not a capable tectonic source. In reviewing the applications for construction permits for abandoned NAPS Units 3 and 4, the applicant indicated that the Atomic Energy Commission (which subsequently became the NRC) accepted this position in its 1974 SER for Units 3 and 4.

In RAI 2.5.3-2, the staff asked the applicant to further support its conclusion that unnamed fault "a" does not extend beyond the ESP site, as mapped by Pavlides (Ref. 36, SSAR Section 2.5). In its response, the applicant stated that the NAPS licensee discovered fault "a" in 1973 during the foundation excavation for the abandoned NAPS Units 3 and 4 and subsequently mapped fault "a" for a distance of about 3000 ft. Virginia Power did not observe fault "a" in the foundation excavations for the existing Units 1 and 2. The applicant stated that Pavlides, who is deceased, did not provide an explanation for extending fault "a" for a total distance of about 7 miles. Subsequently, Mixon and others (Ref. 66, SSAR Section 2.5) adopted Pavlides' interpretation of the extent of fault "a." The applicant stated that Pavlides did not map any offset stratigraphic contacts in the Lake Anna area to support the mapped location of the fault. In addition, a close inspection of the original mapping by Pavlides compared to the compilation map by Mixon shows that the offsets that are apparently mapped in the stratigraphic contacts appear to be a compilation error. The applicant provided further evidence to support its original mapping of fault "a" in response to RAI 2.5.3-1.

Correlation of Earthquake with Capable Tectonic Sources

SSAR Section 2.5.3.3 states that no reported historical earthquake epicenters have been associated with bedrock faults within a 25-mile radius of the ESP site vicinity. The applicant established a seismic monitoring network for NAPS and recorded very small earthquakes (microearthquakes) over a 3.5-year period from 1974 to 1977. The applicant used this monitoring program to determine if seismic activity could be associated with faults in the site area or if Lake Anna was producing reservoir-induced seismicity. The applicant concluded that the microearthquakes detected in the site area could not be associated with either faults in the site area or with the impoundment of Lake Anna. Four of the original 17 seismic monitoring stations in the network were incorporated into the VT Central Virginia Monitoring Network for the specific purpose of monitoring any changes in seismicity in the region of the NAPS. To date, no changes in local earthquake activity have been observed that would alter the conclusions regarding the lack of association of microearthquakes with faults in the site area. Microearthquakes in the site area occur at a level no greater than the spatially varying background activity found in the CVSZ.

Ages of Most Recent Deformations

SSAR Section 2.5.3.4 states that none of the seven faults within 5 miles of the ESP site exhibit evidence of Quaternary activity. All of these faults formed during the Paleozoic Era as part of the Taconic orogeny and may have been reactivated during later Paleozoic orogenies or during the Triassic continental rifting. Based on a review of the available literature and field investigations, the applicant concluded that the seven bedrock faults within 5 miles of the site are old structures that formed during the Paleozoic-age orogenies or early Mesozoic-age rifting.

Relationship of Tectonic Structures in Site Area to Regional Tectonic Structures

SSAR Section 2.5.3.5 states that the seven faults in the site area are located within the Chopawamsic belt, which is interpreted to be an island-arc that was accreted to North America during the Taconic orogeny. Following the Taconic orogeny, rocks of the Chopawamsic belt were deformed and thrust westward during the Acadian and Allegheny orogenies that occurred later during the Paleozoic Era. Extensional tectonics may have also affected the rocks in the Chopawamsic belt during the Mesozoic rifting.

Characterization of Capable Tectonic Sources

SSAR Section 2.5.3.6 states that no capable tectonic sources exist within 5 miles of the ESP site.

Designation of Zones of Quaternary Deformation Requiring Detailed Fault Investigations

SSAR Section 2.5.3.7 states that no zones of Quaternary deformation warrant detailed investigations within the site area.

Potential for Tectonic or Nontectonic Deformation at the Site

SSAR Section 2.5.3.8 states that the ESP site has a negligible potential for tectonic deformation. Since the original studies in the early 1970s, no new information has been reported to suggest the existence of any Quaternary surface faults or capable tectonic sources within the site area. In addition, the site shows no evidence of nontectonic deformation, such as glacially induced faulting, collapse structures, growth faults, salt migration, or volcanic intrusion.

2.5.3.2 Regulatory Evaluation

SSAR Section 2.5.3 describes the applicant's evaluation of the potential for surface deformation that could affect the site. In SSAR Section 1.8, the applicant stated that the information presented in SSAR Section 2.5.3 conforms with the requirements of GDC 2 of Appendix A to 10 CFR Part 50, Appendix S to 10 CFR Part 50, and 10 CFR 100.23. The applicant also stated that it developed the geological, seismological, and geophysical information used to evaluate the potential for surface deformation in accordance with the guidance presented in NUREG-0800, Revision 3, Section 2.5.3, and RGs 1.70, 1.132, 1.165, and 4.7.

In its review of the application, the staff considered the regulatory requirements in 10 CFR 100.23(d)(2), which state that an applicant for an ESP must determine the potential for surface tectonic and nontectonic deformations. The staff notes that application of Appendix S in an ESP review, as referenced in 10 CFR 100.23(d), is limited to defining the minimum SSE for design. Section 2.5.3 of NUREG-0800 and RG 1.165 provide specific guidance concerning the evaluation of information characterizing the potential for surface deformation, including the geological, seismological, and geophysical data that the applicant must provide to establish the potential for surface deformation.

2.5.3.3 Technical Evaluation

This section of the SER provides the staff's evaluation of the seismological, geological, and geophysical investigations carried out by the applicant to address the potential for surface deformation that could affect the site. The technical information presented in SSAR Section 2.5.3 resulted from the applicant's surface and subsurface investigations performed in progressively greater detail as they moved closer to the ESP site. Through its review, the staff determined whether the applicant complied with the applicable regulations and conducted its investigations with an appropriate level of thoroughness.

In order to thoroughly evaluate the surface faulting investigations performed by the applicant, the staff sought the assistance of the USGS. The staff and its USGS advisors visited the ESP site and met with the applicant to assist in confirming the interpretations, assumptions, and conclusions presented by the applicant concerning potential surface deformation. Specific areas of review include the geological investigations (SSAR Section 2.5.3.1), evidence for surface deformation (SSAR Section 2.5.3.2), correlation of earthquake activity with capable seismic sources (SSAR Section 2.5.3.3), ages of most recent deformations (SSAR Section 2.5.3.4), site area and regional tectonic relationships (SSAR Section 2.5.3.5), characterization of capable tectonic sources (SSAR Section 2.5.3.6), Quaternary deformation in the site region (SSAR Section 2.5.3.7), and the potential for surface tectonic deformation at the site (SSAR Section 2.5.3.8).

2.5.3.3.1 Surface Faulting Investigations

The staff focused its review of SSAR Sections 2.5.3.1 through 2.5.3.8 on the adequacy of the applicant's investigations to ascertain the potential for surface deformation that could affect the site. The staff reviewed the applicant's summary of previous site investigations performed for the existing NAPS Units 1 and 2 and the abandoned NAPS Units 3 and 4, as well as recent investigations.

In RAI 2.5.3-1, the staff asked the applicant to provide additional detail on its field investigations and aerial reconnaissance of the site area. In its response, the applicant stated that it performed aerial and field reconnaissance along each of the faults within a 5-mile radius of the ESP site. The staff reviewed the evidence presented by the applicant's response to RAI 2.5.3-1, particularly the applicant's documentation of its field reconnaissance. Specifically, the staff reviewed the applicant's description of its search for evidence of Quaternary deformation for each of the faults, including the applicant's field observations across the Miocene pediment that extends across the region. The staff and its USGS consultants also visited the site area and viewed the continuous, gently inclined Miocene surface referred to in the applicant's response. The staff did not observe any significant vertical displacements that would indicate post-Miocene (5-24 ma) displacement or activity. In summary, the staff and its consultants did not observe evidence for Quaternary activity on any of these local faults and conclude that the applicant has adequately investigated the potential for surface deformation as required by 10 CFR 100.23.

In RAI 2.5.3-2, the staff asked the applicant to further support its conclusion that unnamed fault "a" does not extend beyond the ESP site as mapped by Pavlides (Reference 36, SSAR 2.5.2). In its response, the applicant stated that Virginia Power discovered fault "a" in 1973 during the foundation excavation for the abandoned NAPS Units 3 and 4 and subsequently mapped fault "a" for a distance of about 3000 ft. Virginia Power did not observe fault "a" in the foundation excavations for the existing NAPS Units 1 and 2. The applicant stated that Pavlides, who is deceased, did not provide an explanation for extending fault "a" for a total distance of about 7 miles. Subsequently, Mixon and others (Ref. 66, SSAR Section 2.5.2) adopted Pavlides' interpretation of the extent of fault "a." The applicant stated that Pavlides did not map any offset stratigraphic contacts in the Lake Anna area to support the mapped location of the fault. In addition, the applicant's inspection of the original mapping by Pavlides compared to the compilation map by Mixon showed that the offsets apparently mapped in the stratigraphic contacts appear to be a compilation error. During its field reconnaissance, the applicant found no scarps or lineaments along the extended trace of fault "a" as mapped by Pavlides. The staff notes that the NAPS licensee's trenching of the fault "a" shows that it is most likely a minor fault or bedrock shear within the Ta River metamorphic suite and that it is very unlikely that such a minor fault could be recognized or mapped over a significant distance without a significant number of exposures. The applicant provided further evidence, described above, to support its original mapping of fault "a" in response to RAI 2.5.3-1. Based on this evidence, the staff concludes that fault "a" is unlikely to extend much farther than originally mapped by the applicant.

In SSAR Table 1.9-1, the applicant identified the item "Capable Tectonic Structures or Sources" as an ESP site characteristic. This item specifies that no fault displacement potential exists within the investigative area. As described above, the staff reviewed the applicant's description of unnamed fault "a" in SSAR Section 2.5.3.2.2 and concludes that the ESP site has no fault displacement potential.

Based on its review of SSAR Sections 2.5.3.1 through 2.5.3.8 and the applicant's responses to the RAIs, as set forth above, the staff concludes that the applicant adequately investigated the potential for surface faulting in the site area. The staff concludes that the applicant performed extensive field and aerial reconnaissance of the local faults and concurs with the applicant's assertion that no capable faults exist within the site area. The staff and its USGS consultants also visited the site area and were able to view some of these local faults. Based on its site visit and its review of SSAR Section 2.5.3, as set forth above, the staff concurs with the applicant's conclusion that there is no evidence of Quaternary folding or faulting that could be associated with these local faults.

2.5.3.4 Conclusions

In its review of the geologic and seismologic aspects of the ESP site, the staff considered the pertinent information gathered by the applicant during the regional and site-specific geological, seismological, and geophysical investigations. As a result of this review, described above, the staff concludes that the applicant performed its investigations in accordance with 10 CFR 100.23 and RG 1.165 and provided an adequate basis to establish that no capable tectonic sources exist in the site vicinity that would cause surface deformation in the site area. The staff concludes that the site is suitable from the perspective of tectonic surface deformation and meets the requirements of 10 CFR 100.23.

2.5.4 Stability of Subsurface Materials and Foundations

SSAR Section 2.5.4 presents information on the stability of subsurface materials and foundations at the ESP site. SSAR Section 2.5.4.2 describes the engineering properties of the subsurface materials, SSAR Section 2.5.4.3 summarizes both the previous subsurface investigations and ESP exploration program, SSAR Section 2.5.4.4 summarizes geophysical investigations performed at the site, SSAR Section 2.5.4.5 describes the extent of anticipated excavations, fills, and slopes, Section SSAR 2.5.4.6 describes the ground water conditions at the site, SSAR Section 2.5.4.7 provides the response of subsurface materials to dynamic loading, and SSAR Section 2.5.4.8 describes the liquefaction potential of the site. SSAR Sections 2.5.4.1, 2.5.4.9, and 2.5.4.11 refer to topics that the SSAR covers in greater detail elsewhere. Finally, SSAR Section 2.5.4.12 summarizes techniques that would be used to improve subsurface conditions.

2.5.4.1 Technical Information in the Application

2.5.4.1.1 Geologic Features

SSAR Section 2.5.4.1 refers to the description of regional and site geologic features in SSAR Sections 2.5.1.1 and 2.5.1.2. Section 2.5.1.3 of this SER contains the technical evaluation of this information.

2.5.4.1.2 Properties of Subsurface Materials

SSAR Section 2.5.4.2 describes the static and dynamic engineering properties of the ESP site subsurface materials. Section 2.5.4.2 also describes the subsurface materials, as well as laboratory test results and the engineering properties of the subsurface materials.

<u>Description of Subsurface Materials</u>

The applicant stated that it derived the properties of the subsurface materials encountered at the site from 140 subsurface borings made to date at both the NAPS and the ESP sites. The applicant divided the subsurface materials into five zones and described them as summarized below. Figures 2.5.4-1 and 2.5.4-2, reproduced from SSAR Figures 2.5-57 and 2.5-58, show two subsurface profiles (A-A' and B-B') that depict the layering of each of the soil and rock zones beneath the ESP site as well as the ESP borehole locations.

Zone IV Bedrock

Zone IV is composed of fresh to slightly weathered gneiss, which is a metamorphic rock that exhibits a banded texture (foliation) in which light and dark bands alternate. Gneiss is composed of feldspar, quartz, and one or more other minerals such as mica and hornblende. The top of the Zone IV (including Zone III-IV) bedrock at the ESP site ranges from an elevation of 188 to 298 ft.

Zone III Weathered Rock

The weathered rock has the same constituents as the parent rock. It is described as moderately to highly weathered rock, sometimes with unweathered seams and sometimes with a high fracture frequency. It is defined as having at least 50 percent core stone. The top of the Zone III bedrock at the ESP site ranges from an elevation of 205 to 298 ft.

Zone IIA and IIB Saprolites

Saprolites are a further stage of weathering beyond weathered rock. They have been produced by the disintegration and decomposition of the bedrock in place and have not been transported. Although classified as soils, saprolites contain the relict [remnant] structure of the parent rock, as well as some core stone of the parent rock. The ESP site saprolites in many instances maintain the foliation characteristics of the parent rock. They are classified primarily as silty sands, although there are also sands, clayey sands, sandy silts, clayey silts, and clays, depending on their degree of weathering. The fabric is anisotropic. The texture shows angular geometrically interlocking grains with a lack of void network, very unlike the well-pronounced voids found in marine or alluvial sands and silts.

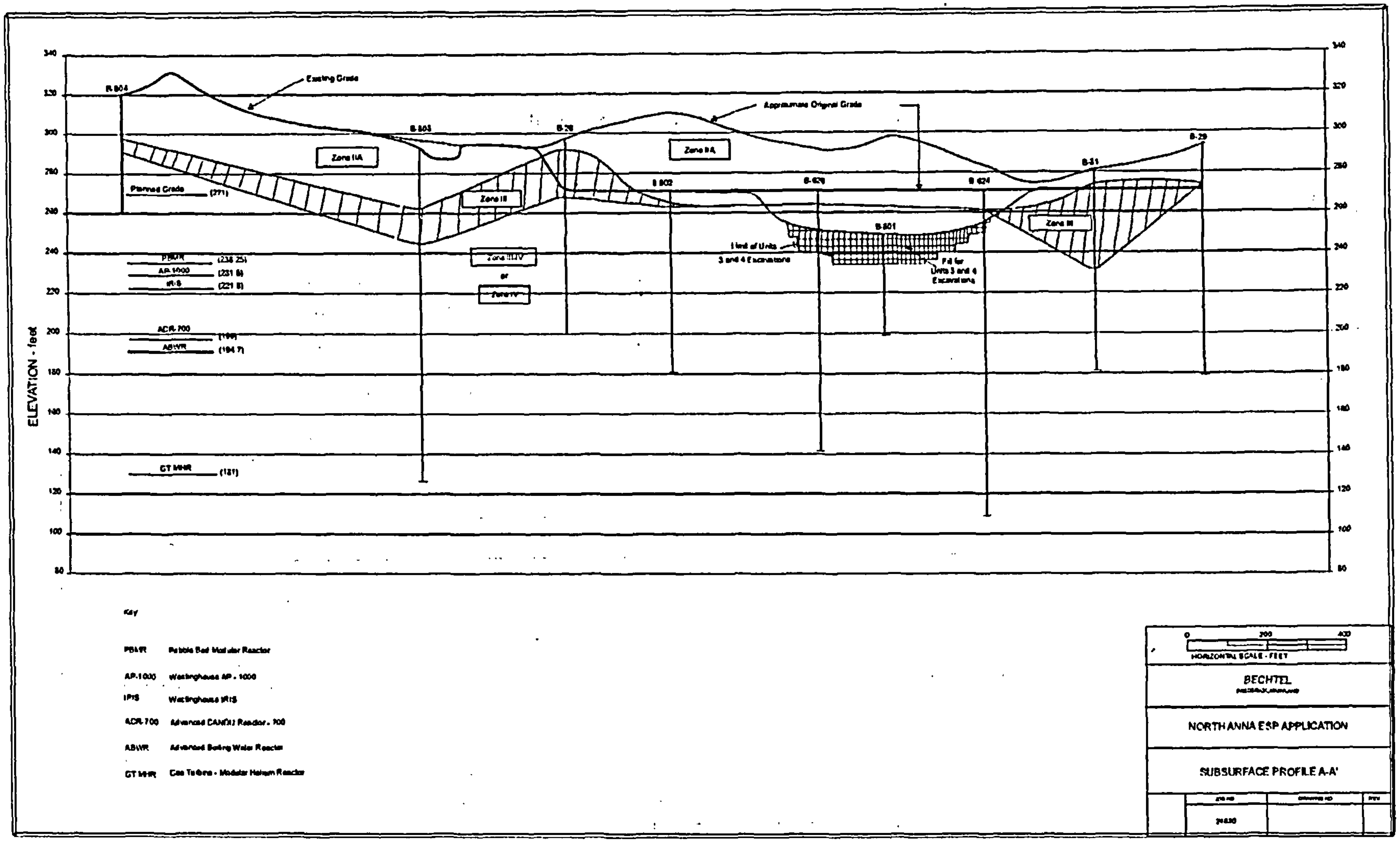


Figure 2.5.4-1 Subsurface Profile A-A'

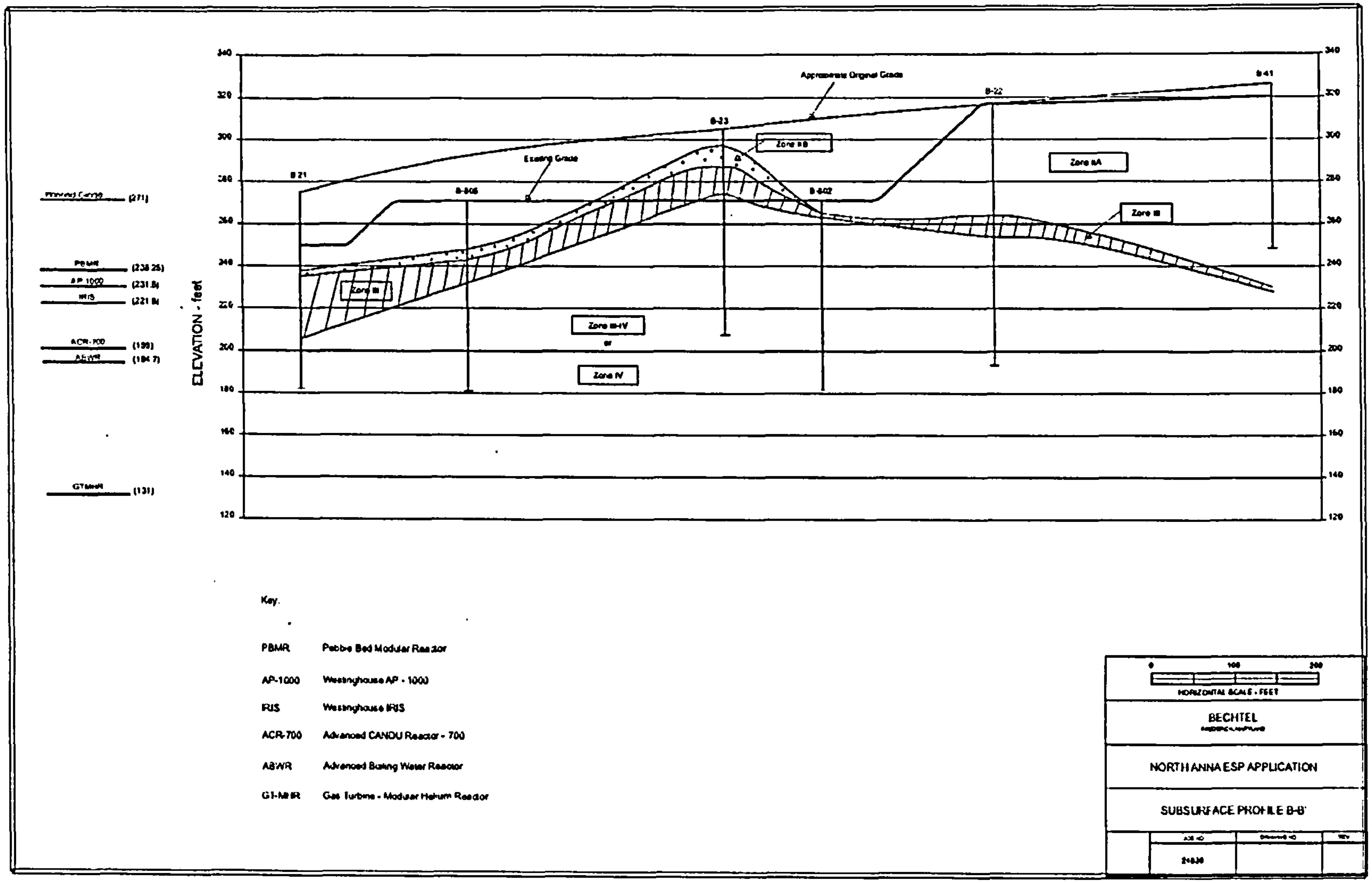


Figure 2.5.4-2 Subsurface Profile B-B'

The distribution of the Zone IIA and IIB saprolites varies throughout the site. On average, the Zone IIB saprolites represent about 20 percent of the saprolites on site and are typically very dense, silty sands with 10 to 50 percent core stone. The thickest Zone IIB deposit encountered in the borings is 37 ft. The overlying Zone IIA saprolites comprise, on average, about 80 percent of the saprolitic materials on site. About 75 percent of the Zone IIA saprolites are classified as coarse grained (sands, silty sands), while the remainder are fine grained (clayey sands, sandy and clayey silts, and clays). The saprolites typically become finer toward the ground surface. The thickest Zone IIA deposit encountered in the borings is 101 ft.

Zone I and Fill

Typically, very little Zone I residual soil exists onsite; on average, less than one percent of the soil is Zone I. The Zone I soils are either at the surface or are immediately below the fill placed during construction of the earlier units. This fill generally consists of Zone IIA soils.

Laboratory Testing

SSAR Section 2.5.4.2.4 describes the results of numerous laboratory tests of soil and rock samples performed previously, as well as the new tests performed for the ESP site investigation. The applicant performed the large majority of the tests on the Zone IIA saprolite soils for the various investigations for the SWR for the existing NAPS units; the following briefly summarizes these investigations.

Laboratory Tests for the SWR

The laboratory testing of the SWR soils focused on the strength, compressibility, and liquefaction potential of the Zone IIA saprolites. The tests include (1) cyclic triaxial tests to provide input for analysis of the liquefaction potential of the soils, (2) static triaxial shear tests including both consolidated-undrained as well as unconsolidated-undrained tests to determine shear strength parameters, (3) consolidation tests to determine the deformation behavior under various loadings, and (4) examinations of thin sections to determine the fabric, texture, and mineralogy of the saprolite. Appendix A to SSAR Section 2.5.4 presents the results of the laboratory testing of the SWR soils, which the applicant used to determine liquefaction potential, static stability, and the response of the soil to dynamic loading.

Laboratory Tests for ESP

The applicant performed laboratory testing for the ESP investigation to verify the large number of test results for previous investigations. The ESP tests focused on (1) verifying the basic properties of the Zone IIA saprolite, (2) obtaining chemical tests on the Zone IIA saprolites for corrosiveness toward buried steel and aggressiveness toward buried concrete, and (3) obtaining additional strength and elastic modulus data for the bedrock on which the main safety-related structures might be founded. Appendix B to SSAR Section 2.5.4 presents the results of the ESP laboratory tests, summarized for soil in SSAR Table 2.5-43 and for rock in SSAR Table 2.5-44. The results listed in these SSAR tables include (1) Atterberg limits (i.e., liquid, plastic, and plasticity), (2) sieve weight percentages using a #200 sieve (0.075 mm opening), and (3) soil chemistry (i.e., pH, chlorides, and sulfates). The applicant stated that the ESP laboratory test results are similar to those obtained from previous testing.

Engineering Properties

Table 2.5-45 of the SSAR presents the engineering properties of materials in subsurface Zones IIA, IIB, III, III-IV, and IV, which the applicant derived from the previous studies and from ESP field exploration and laboratory testing programs. These properties include standard geotechnical parameters such as natural moisture content, undrained shear strength, effective cohesion, effective friction angle, total unit weight, standard penetration test (SPT) blow count values, shear and compression wave velocities, elastic and shear moduli, consolidation characteristics, and static earth pressure coefficients. The following sections describe the sources and/or methods used to develop the selected properties shown in SSAR Table 2.5-45.

Rock Properties

The results given in SSAR Table 2.5-41 provide the basis for the recovery and rock quality designations (RQDs). The ESP rock strength results shown in SSAR Table 2.5-44 and the rock strengths from the investigations for the existing units form the basis for the unconfined compressive strength. The unit weight is based on the values measured in the ESP rock strength tests (SSAR Appendix 2.5.4B).

The elastic modulus values are based on the values shown in SSAR Table 2.5-44. These values agree well with those derived from the geophysical tests performed for the ESP exploration program, as described in SSAR Section 2.5.4.4.2. The shear modulus values are derived from the elastic modulus values using the Poisson's ratio values given in SSAR Table 2.5-45, which are based on the values provided in SSAR Table 2.5-44. Low- and high-strain modulus values are essentially the same for high-strength rock (i.e., for the Zone IV rock). Similarly, no strain softening is assumed for the Zone III-IV rock. The shear and compression wave velocities are based on the crosshole and downhole seismic tests performed as part of the ESP exploration program. These results, summarized in SSAR Section 2.5.4.4.2, agree with those of the geophysical tests performed for the existing units.

In RAI 2.5.4-2(a), the staff asked the applicant to describe the extent of severely weathered fracture zones in the Zone III-IV and IV rock that Virginia Power observed during the site investigation for abandoned Units 3 and 4. The applicant observed similarly fractured rock in four of the seven ESP borings. In response to RAI 2.5.4-2, the applicant provided a table that shows an RQD of less than 25 percent in nine of the borings for abandoned Units 3 and 4. The applicant noted that most of the rock thicknesses for the low RQD intervals (less than 10 percent) are only 1 to 2 ft thick. In RAI 2.5.4-2(b), the staff asked the applicant to describe the impact of these fractured rock zones on the suitability of the site to host safety-related structures. In response to RAI 2.5.4-2(b), the applicant stated the following:

> As noted in these SSAR sections, any weathered or fractured zones encountered at foundation level would be excavated and replaced with lean concrete. If such zones exist below sound rock beneath the foundation, they would have no impact on the stability of the foundation, since these zones are typically only 0.5 to 1-foot thick, and are confined within an unfractured rock mass with strengths of 4,000 to 12,000 psi (compared to the maximum foundation pressure of just over 100 psi). The foundation itself would consist of a large, thick, highly-reinforced concrete mat that is so stiff that it cannot logically yield.

Multiple borings would be performed at each structure location once the building locations are chosen as part of detailed engineering. These borings would identify whether there are any thicker fracture zones beneath the foundation than those encountered in the ESP borings and in the abandoned Units 3 and 4 borings. If any thicker zones are found, analysis would be performed to identify their impact on foundation stability. If they are close enough to the foundation to potentially impact stability, they would be excavated and replace with lean concrete.

Soil Properties

Grain size curves from 13 sieve analyses of Zone IIA silty sand samples from the ESP laboratory testing program fit within the envelope of the 12 sieve analyses of Zone IIA silty sands sampled from borings near the SWR pump house. The natural moisture content of the fine-grained Zone IIA saprolite, determined from the moisture content tests performed on fine-grained Zone IIA saprolites for the past and the present (ESP) investigations, ranges from 14 to 56 percent.

The applicant estimated undrained shear strength of the fine-grained Zone IIA saprolite from SPT –values and cone penetrometer test (CPT) results, as well as from the results of 18 unconsolidated-undrained triaxial compression tests and 3 unconfined compression tests. The effective strength parameters for the fine-grained saprolite are based on the results of consolidated-undrained triaxial tests on fine-grained saprolite run for the previous ISFSI (Ref. 6, SSAR Section 2.5) and SWR investigations (Appendix A to SSAR Section 2.5.4).

The applicant stated that it would typically assume an effective angle of internal friction of the medium-dense coarse-grained saprolite (N=20 blows/ft) of about 35 degrees. However, the high silt content and the presence of low-plasticity clay minerals reduce this angle. Consolidated-undrained triaxial tests reported in Appendices 2C and 3E to the UFSAR for the existing units produced internal friction angles ranging from 23 to 33 degrees, with a median of 30.8 degrees. Thus, the applicant selected an angle of 30 degrees. The average effective cohesive component from the UFSAR Appendix 2C tests is 0.275 kps per square foot (ksf). The applicant selected a value of 0.25 ksf for the cohesive component.

Based on a large amount of testing performed after low unit weights were measured in the Zone IIA saprolites in the SWR area, the NAPS licensee concluded that there are isolated lower densities, but that these are not typical. Table 3.8-13 of the NAPS UFSAR identifies 125 pounds per cubic foot (pcf) as a design total unit weight. The 130 pcf shown in SSAR Table 2.5-45 for the Zone IIB saprolites reflects the high relative density of that material.

The applicant stated that the SPT design N-value of 20 blows/ft for the Zone IIA saprolite is conservatively based on the results reported in SSAR Table 2.5-40. Those results show median N-values for the ESP and ISFSI investigations of 21 blows/ft, with the median N-values for the existing units, abandoned Units 3 and 4, and SWR investigations ranging from 25 to 52 blows/ft.

The shear wave velocities measured in the ESP crosshole seismic tests in the Zone IIA sandy silt from a depth of 7.5 to 27 ft range from 650 to 1350 ft/s, with an average of 998 ft/s. The CPT seismic results are somewhat higher. The UFSAR has a value of 950 ft/s for the Zone IIA saprolite. The applicant selected a value of 950 ft/s for the Zone IIA saprolite, as shown in SSAR Table 2.5-45. For the Zone IIB saprolite, the shear wave velocity derived from the low strain value of shear modulus agrees well with the results from the CPT seismic tests, at around 1600 ft/s. Section 2.5.4.7 of the SSAR gives the profile of shear wave velocity versus depth for the saprolite.

The applicant derived the high-strain (i.e., in the range of 0.25 to 0.5 percent) elastic modulus values for the coarse-grained Zone IIA saprolite and the Zone IIB saprolite using the relationship with the SPT –value given in the literature (Ref. 151, SSAR Section 2.5). In addition, the applicant derived the high-strain elastic modulus for the fine-grained Zone IIA saprolite using the relationship with undrained shear strength (also given in SSAR Ref. 151). The applicant stated that it slightly adjusted the Zone IIA coarse- and fine-grained values to obtain a common value.. The applicant obtained the shear modulus (G) values from the elastic modulus values using the relationship between elastic modulus (E), shear modulus, and Poisson's ratio (ν).

$$G = \frac{E}{2(1+\nu)}$$

The applicant derived the low-strain (i.e., 10^{-4} percent) shear modulus for the Zone IIA saprolite from the shear wave velocity of 950 ft/s. Similarly, the applicant derived the low-strain shear modulus (G_{max}) of the Zone IIB saprolite from the shear wave velocity of 1600 ft/s. The applicant obtained the elastic modulus values for the Zone IIB saprolite from the shear modulus values using the relationship between elastic modulus, shear modulus, and Poisson's ratio (Ref. 150, SSAR Section 2.5).

The values derived from the settlement studies performed for the SWR pump house, as detailed in Appendix 3E to the UFSAR, include the recompression ratio (total amount of settlement) and the coefficient of secondary compression (after primary consolidation). The values of unit coefficient of subgrade reaction are based on values for medium-dense sand (Zone IIA saprolite) and very dense sand (Zone IIB saprolite) provided by Terzaghi (Ref. 152, SSAR Section 2.5). The earth pressure coefficients (ratio of lateral load to vertical load) are Rankine values, assuming level backfill and a zero friction angle between the soil and the wall.

In RAI 2.5.4-4, the staff asked the applicant to explain how the total thickness of the soil layers sampled at the ESP site (105 ft) is sufficient to characterize the soil properties underlying the site. The applicant responded that the 138 borings previously performed by Virginia Power for Units 1 and 2 as well as the abandoned Units 3 and 4 characterize the soils at the North Anna site very well. The applicant stated that the soils in all of borings show the same general subsurface profile and that it used the ESP borings to show that the soil (and rock) profiles in each of the borings fit within the general subsurface profile.

Chemical Properties

The applicant performed chemical tests on selected Zone IIA samples. In addition to the tests performed for the ESP site investigation (see the results shown in SSAR Table 2.5-43), Virginia Power previously performed chemical tests on two samples from the subsurface investigation for the existing units. The six pH test results range from 5.7 to 6.9, in the mildly corrosive to neutral range. The six sulfate test results range from about 1 to 28 parts per million, indicating no aggressiveness toward concrete. Three of the chloride test results range from 100 to 170 milligrams per kilogram (mg/kg), indicating little corrosive potential toward buried steel. The fourth chloride test produced 920 mg/kg, indicating potential corrosiveness toward buried steel.

2.5.4.1.3 Exploration

SSAR Section 2.5.4.3 describes the previous subsurface investigations performed at the NAPS site as well as the ESP exploration program.

Previous Subsurface Investigation Programs

For the existing Units 1 and 2, the NAPS licensee performed 60 borings in 1968, with boring depths ranging from 20 to 150 ft. For the abandoned Units 3 and 4, Virginia Power performed 47 borings in 1971, with boring depths ranging from 40 to 175 ft. Virginia Power performed an additional 22 borings in the SWR area after 1976, as well as 9 borings in 1994 for the ISFSI. The borings used SPT sampling, Dames and Moore soil samplers, and NX-size double-tube core barrels for rock coring. SSAR Tables 2.5-30 through 2.5-37 summarize the boring locations, the elevations for each of the subsurface zones, and RQDs. Figure 2.5.4-3, reproduced from SSAR Figure 2.5-59, shows the locations of the previous borings.

In RAI 2.5.4-3, the staff asked the applicant to describe how it integrated the NAPS licensee's site investigations for the SWR and the ISFSI with its field investigations for the ESP site. The applicant responded that the SWR and ISFSI borings are as close to the ESP area as any other borings and disclosed the same subsurface profile displayed by the other borings at the North Anna site (see SER Figure 2.5.4-3). In addition, the applicant stated that it used some of the SWR and ISFSI borings, which are close to the southeast corner of the ESP footprint, noted in RAI 2.5.4-1, to help characterize the ESP area.

ESP Subsurface Investigation Program

The applicant stated that it performed the ESP subsurface investigation in 2002, covering the area proposed for the new units and the cooling towers for the new units. This investigation consisted of relatively few exploration points, compared to previous field explorations for the existing units, abandoned units, SWR, and ISFSI. According to the applicant, it designed the ESP field explorations primarily to confirm the results obtained from the previous extensive investigations. The applicant stated that it would perform additional structure-specific exploration and testing during detailed engineering, and a COL application would describe this testing. Figure 2.5.4-4, reproduced from SSAR Figure 2.5-60, shows the ESP exploration point locations.

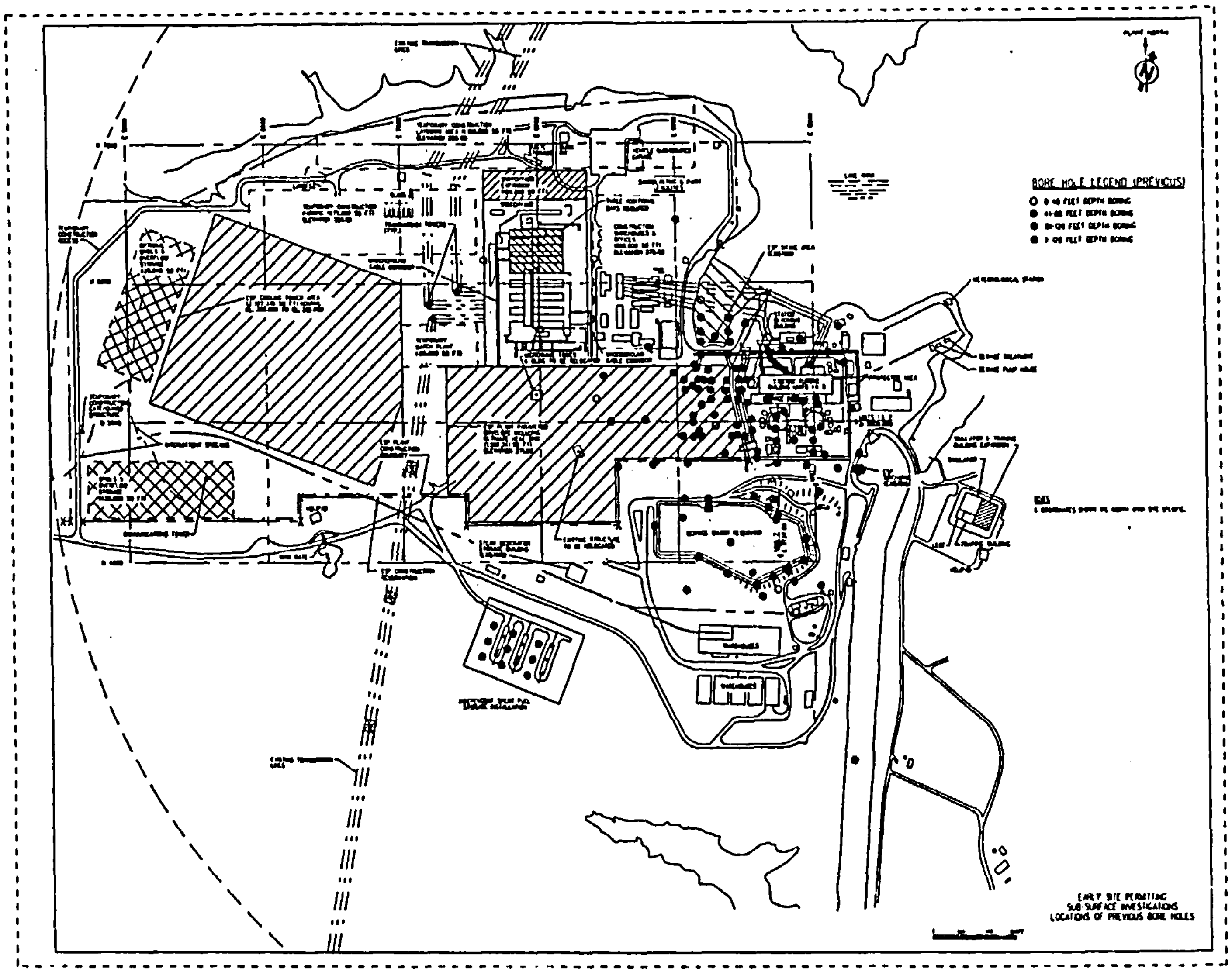


Figure 2.5.4-3 Locations of previous boreholes

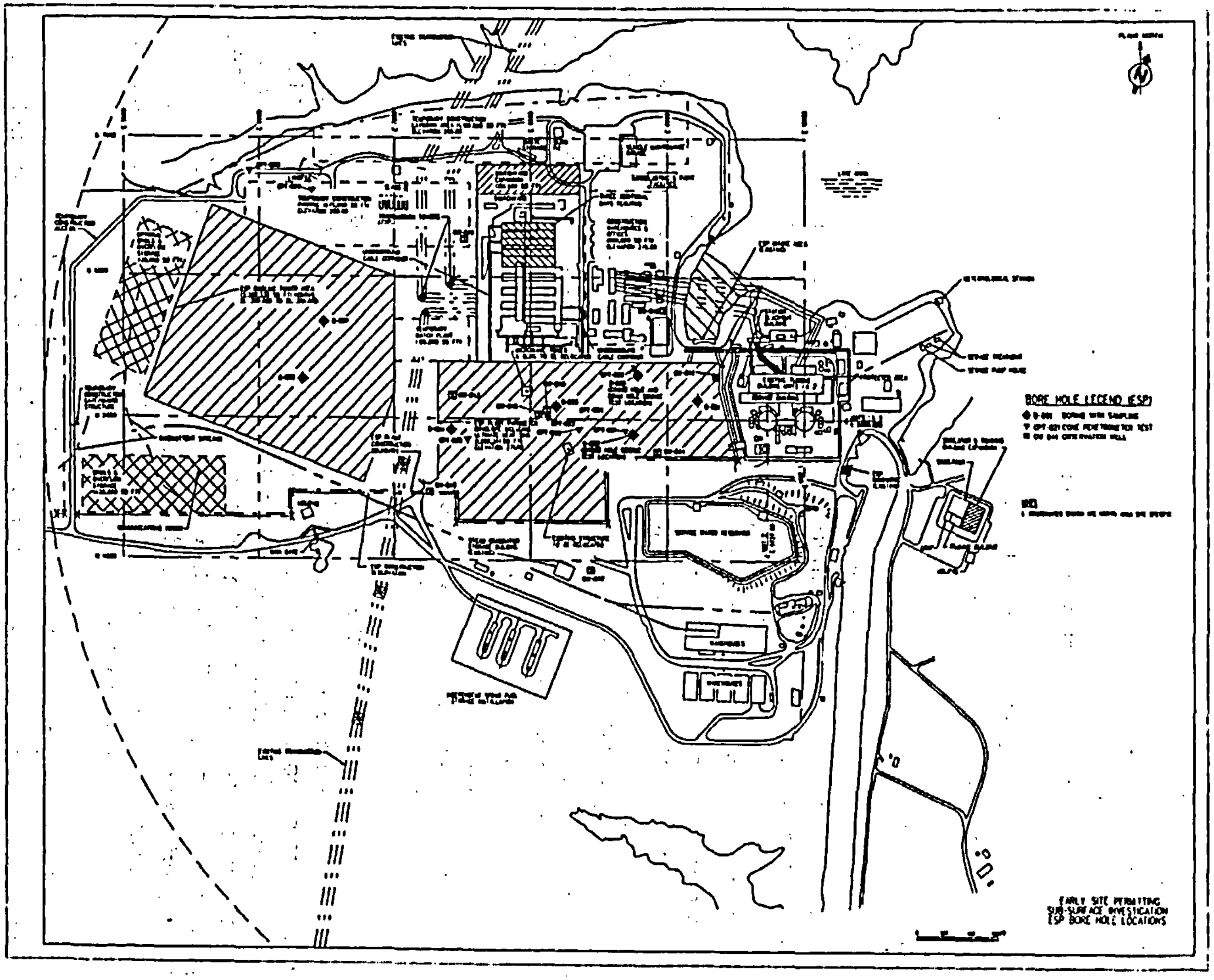


Figure 2.5.4-4 ESP borehole locations

The scope of work related to the ESP site investigation consisted of the following:

- seven exploratory borings
- nine observation wells
- eight CPTs
- two downhole seismic cone tests
- two pore pressure dissipation tests
- two sets of crosshole seismic tests
- one downhole seismic test
- a survey of all exploration points
- laboratory testing of borehole samples and cores

Appendix B to SSAR Section 2.5.4 provides details and results of the exploration program. The following summarizes the borings, observation wells (OWs), and CPTs.

Borings and Samples/Cores

According to the applicant, the seven borings drilled range from 50 to 170 ft in depth, averaging 85 ft. The 170-ft deep boring is 30 ft deeper than the deepest reactor design considered for the ESP. The applicant stated that it conducted the SPT in general accordance with American Society for Testing and Materials (ASTM) D1586 and performed rock coring in general accordance with ASTM D2113. The applicant stated that, after removal from the split inner barrel, it carefully placed the recovered rock in wooden core boxes. The onsite geologist visually described the core, noting the presence of joints and fractures and distinguishing natural breaks from mechanical breaks. The geologist also computed the percentage recovery and the RQD. Appendix B to SSAR Section 2.5.4 provides the boring logs and the photographs of the rock cores. These boring logs describe in detail the soil and rock materials encountered at different depths of the borings and also contain a record of the ground water level, the SPT blow counts, and the elevation of the top of the rock surface. The applicant used these data for the liquefaction analyses, bearing capacity calculations, and settlement analyses. The applicant stated that the soil and rock materials encountered in the ESP borings are similar to those found in the previous sets of borings conducted at the NAPS site.

In RAI 2.5.4-1, the staff asked the applicant to provide its basis for concluding that the subsurface conditions in the southeast portion of the ESP footprint (an area of about 500 ft by 1000 ft, in which there are no borings) do not materially differ from conditions in adjacent areas where borings were made. In its response, the applicant stated that the North Anna site is underlain by a consistent geologic profile, which extends to a depth of several thousand feet. The 145 borings performed throughout the North Anna site (including 7 for the ESP) indicate a consistent overall subsurface profile, with expected variations in the thickness of the various strata. As such, the applicant concluded that the southeast portion of the ESP footprint (see SER Figure 2.5.4-3) should be similar to the rest of the site.

In RAI 2.5.4-6, the staff asked the applicant to explain why it did not provide laboratory test results from the borings of subsurface materials over various depth intervals. The applicant responded that the containment (reactor) buildings for the new units would be founded on the Zone III-IV and/or Zone IV metamorphic gneiss bedrock at the North Anna site. Rock coring and testing performed by Virginia Power for Units 1 and 2 gave unconfined compressive strengths for the Zone III-IV and IV rock ranging from 1,000 to 16,300 psi with a median strength of 6,800 psi. The applicant stated that these rock strengths are typical for this type of rock and more than sufficient to support the maximum containment (reactor) building loads of about 100 psi. The applicant added that, during logging of the rock cores in the field for the ESP investigation, it was apparent that the metamorphic rock is a strong material. The applicant stated that it performed sufficient tests on the ESP cores to verify that the rock strengths are similar to or higher than those cores tested for Units 1 and 2. The applicant determined that the median value of the unconfined compressive strengths of the Zone III-IV and IV rock from the ESP investigation is 18,400 psi.

Observation Wells

The applicant screened eight OWs with depths ranging from about 25 to 50 ft in soil and/or weathered rock. The applicant advanced boreholes for these wells with hollow stem augers. The applicant obtained samples at 5-ft intervals to provide information on an appropriate depth to set the slotted screen. The applicant screened the ninth well in rock. Each well was developed by pumping. The applicant considered the well developed when the pH and conductivity stabilized and the pumped water was reasonably free of suspended sediment. The applicant then performed permeability tests in each well in general accordance with ASTM D4044, Section 8, using the slug test method. Appendix B to SSAR Section 2.5.4 contains the details of the boring logs for the OWs, the well installation records, the well development records, and the well permeability test results. The boring logs of the OWs also describe the soil and rock seen in these borings. The applicant stated that it would use the ground water level data, as recorded in the OWs, in developing the dewatering program at the time of construction.

Cone Penetrometer Tests

The applicant stated that it advanced each of the CPTs to refusal (i.e., no further penetration), to depths ranging from 4 to 58 ft. The applicant stated that it performed the piezocone tests in general accordance with ASTM D5778. The pore pressure filter was located immediately behind the cone tip. The applicant performed pore pressure dissipation tests at a depth of 27 ft in CPT-823 and at a depth of 32.5 ft in CPT-827. Appendix B to SSAR Section 2.5.4 contains the CPT logs, shear wave arrival times, and pore pressure versus time plots, while SSAR Tables 2.5-38 and 2.5-39 summarize the CPT locations and depths.

2.5.4.1.4 Geophysical Surveys

<u>Previous Geophysical Survey Programs</u>

The NAPS licensee performed several geophysical studies for the investigation for the existing Units 1 and 2, including a seismic refraction survey in 1968. The seismic (compressional wave) velocities measured by Virginia Power in the relatively unweathered rock (Zone IV) range from 13,000 to 16,000 ft/s. Compressional wave velocities measured in weathered rock are around 5000 ft/s. Shear wave velocities in the Zone IV rock range from about 4000 to 8000 ft/s. The corresponding compressional wave velocities are about 8,000 to 16,000 ft/s. Unit weights range from about 140 to 170 pcf. Weston Geophysical performed seismic crosshole tests between the Unit 1 and 2 reactors and obtained shear wave velocities in the Zone IV rock between 5000 and 6000 ft/s. The UFSAR for the existing units provides a shear wave velocity for the saprolite (Zone IIA) of 950 ft/s.

Geophysical Surveys for ESP

For the ESP site geophysical investigation, the applicant performed two crosshole seismic tests, one downhole seismic test in a borehole, and two downhole seismic tests using a cone penetrometer.

Crosshole Seismic Tests

The applicant performed crosshole seismic tests immediately adjacent to borings B-802 and B-805. The applicant stated that it performed these tests in accordance with ASTM D 4428/D 4428M. The applicant used the B-802 location to obtain readings in rock, while it used the B-805 location to obtain readings in soil. The applicant performed tests in boring B-802 at 5-ft intervals in the rock at depths ranging from 27 to 90 ft; however, it only obtained shear wave velocity results at depths ranging from 27 to 45 ft. The applicant stated that severe high-frequency noise appears to have degraded the results in general, but particularly below a depth of 45 ft. The high-frequency noise obscured all of the compressional wave forms. The shear wave velocities in the rock at depths between 27 and 45 ft range from 4500 to 6000 ft/s. The applicant performed tests in borings B-805A, B, and C at 2.5- to 5-ft intervals in the soil from near the surface to a depth of 27 ft. The seismic waveforms were reasonably clear, except for the bottom interval, close to the rock interface. The shear wave velocities range from about 610 to 1380 ft/s, the compressional wave velocities range from about 1240 to 6550 ft/s, and the computed dynamic Poisson's ratios range from 0.27 to 0.49.

Downhole Seismic Tests

Since the crosshole tests in borings B-802A, B, and C yielded no compressional wave results and gave no shear wave velocity results below a depth of 45 ft, the applicant conducted downhole seismic testing in boring B-802B. Appendix B to SSAR Section 2.5.4 contains a detailed description of the results. The applicant stated that the shear wave was reasonably well defined to a depth of 45 ft, less defined from a depth of 45 to 65 ft, and not defined below a depth of 65 ft. Between 22.5 and 65 ft, shear wave velocities range from about 3400 ft/s to 6380 ft/s. Between 22.5 and 87 ft, compressional wave velocities range from about 10,000 ft/s to 16,600 ft/s. The computed dynamic Poisson's ratios range from 0.38 to 0.45.

Downhole Seismic Tests with Cone Penetrometer

The applicant performed downhole seismic tests at 5-ft intervals in CPT-822 and CPT-825. It recorded shear waves with a geophone attached near the bottom of the cone string. Appendix B to SSAR Section 2.5.4 plots shear wave arrival times versus depth. In CPT-822, the computed shear wave velocity between depths of 10 and 22 ft was about 1275 ft/s. In CPT-825, the computed shear wave velocity between depths of 6 and 30 ft was 1175 ft/s. For greater depths, between 30 and 45 ft, the computed shear wave velocity was about 1660 ft/s, and between 45 and 52 ft, it was about 2438 ft/s.

In RAI 2.5.4-5, the staff asked the applicant to explain why SSAR Table 2.5-45 does not give shear wave velocities for Zone IIB saprolite and Zone III and III-IV weathered rock. In its response, the applicant stated that SSAR Table 2.5-45 gives average shear wave velocities for Zones IIB, III, and III-IV but does not provide a range of values. In contrast, it provides both average values and a range of shear wave velocity values for Zones IIA and IV. According to the applicant, it originally provided only average values for Zones IIB, III, and III-IV because the ESP borings did not sample these zones as abundantly as Zones IIA and IV. In response to this RAI, the applicant provided its method for determining the average shear wave velocity values for Zones IIB (1600 ft/s), III (2000 ft/s), and III-IV (3300 ft/s). In addition, the applicant used its laboratory measurements of the soil/rock properties for Zones IIB, III, and III-IV to indirectly determine the shear wave velocities. Accordingly, the applicant updated SSAR Table 2.5-45 to include the range in shear wave velocity for these three soil/rock zones.

2.5.4.1.5 Excavation and Backfill

SSAR Section 2.5.4.5 describes the extent of anticipated safety-related excavations, fills, and slope; excavation methods and stability; backfill sources and quality control; and construction dewatering impacts. The applicant stated that the construction of the proposed new units would involve a substantial amount of excavation in both soil and rock. Filling would consist almost entirely of backfilling around structures back up to plant grade. The only new permanent slope that may be created would be to the west of the SWR to accommodate the buried UHSs, if warranted by the selected design for the proposed additional units. The applicant stated that the top of the slope would be at least 200 ft from the top of the SWR embankment and, therefore, would not impact the SWR. Next, the applicant described excavation methods that it would use in soil and rock (i.e., blasting techniques and alternatives to blasting), backfill sources, and quality control. The applicant stated that structural fill would be either lean concrete or a sound, well-graded granular material. In addition, it would establish an onsite soils testing laboratory to control the quality of the fill materials and the degree of compaction. To control soil erosion, the applicant stated that it would line any sumps and ditches constructed for dewatering and slope the tops of excavations back to prevent runoff down the excavated slopes during heavy rainfall.

2.5.4.1.6 Ground Water Conditions

In SSAR Section 2.5.4.6, the applicant briefly described the ground water conditions at the ESP site and general plans for construction dewatering. Section 2.4.12 of the SSAR describes the ground water conditions at the ESP site in detail. The following summarizes the applicant's description of the ESP site ground water conditions in SSAR Section 2.5.4.6.

Nine OWs installed at the site as part of the ESP subsurface investigation program have exhibited ground water levels ranging from MSL elevations of 241 to 311 ft between December 2002 and June 2003. Based on the results of the slug tests in the wells, hydraulic conductivity values for the saprolite in which eight of the wells were screened range from 0.2 to 3.4 ft/day. The applicant estimated the hydraulic conductivity of the shallow bedrock in which one of the wells was screened to be about 2 to 3 ft/day. Ground water movement at the site is generally to the north and east, toward Lake Anna.

The applicant stated that ground water is present in unconfined conditions in both the surficial sediments and underlying bedrock at the ESP site. The ground water generally occurs at depths ranging from about 6 to 58 ft below the present-day ground surface. The design ground water level for the new units would range from 265 to 270 ft MSL in elevation. Section 2.4.12 of the SSAR derives this level.

The applicant stated that it can achieve dewatering for all major excavations using gravity-type systems. For soils, because of their relatively impermeable nature, sump-pumping of ditches would be adequate to dewater the soil. For rock, the applicant would use sump-pumping to collect water from relief drains that would be installed in the major rock excavation walls to prevent hydrostatic pressure buildup behind the walls.

2.5.4.1.7 Response of Soil and Rock to Dynamic Loading

In SSAR Section 2.5.4.7, the applicant estimated the seismic ground motion amplification/attenuation using the shear wave velocity profiles for the different subsurface materials, the variation of shear modulus and damping with strain, and the site-specific acceleration time histories. The applicant stated that the reactor containment buildings for the proposed additional units would be founded on Zone III-IV or Zone IV bedrock. However, other safety-related structures may be founded on the Zone III weathered bedrock, the Zone IIB very dense saprolitic sand, and/or the Zone IIA saprolitic sand.

Shear Wave Velocity Profile

The applicant made various measurements, summarized in SSAR Section 2.5.4.4, at the ESP site to obtain estimates of the shear wave velocity in the soil and rock. The applicant considered the Zone IV bedrock to be the base rock at a depth of 70 ft in the amplification/attenuation analysis. Table 2.5-45 of the SSAR shows an average shear wave velocity of 6300 ft/s for Zone IV. While in some locations the top of Zone III-IV or Zone IV bedrock is found close to or even above the planned plant grade, sound bedrock is relatively deep in other locations. The applicant stated that, in the case of relatively deep bedrock, some safety-related structures (excluding the reactors) may be founded on the Zone III weathered rock, Zone IIB saprolite, or Zone IIA saprolite. SSAR Figure 2.5-62, Profile (a), focuses on this situation; it shows the shear wave velocity values measured in Zone IIA saprolite for the ESP subsurface exploration program using crosshole and CPT downhole seismic testing. SSAR Figure 2.5-62 (reproduced previously as SER Figure 2.5.2-5) also shows the shear wave velocity of 950 ft/s given in the UFSAR of the existing units for the saprolite. The applicant took this as the average design value for the Zone IIA saprolite for the ESP evaluation. The design shear wave velocity versus depth profile shown in SSAR Figure 2.5-62, Profile (a), is anchored about the design value of 950 ft/s for the Zone IIA saprolite but reflects the expected increasing values with depth demonstrated in the crosshole and downhole seismic tests.

The applicant stated, as noted in SSAR Section 2.5.4.10.2, that it would improve any Zone IIA saprolites supporting safety-related structures to reduce potential settlement. In RAI 2.5.4-7, the staff asked the applicant to reconcile two conflicting statements in SSAR Sections 2.5.4.7.1 and 2.5.1.2.6. The applicant stated in SSAR Section 2.5.1.2.6 that Zone III (weathered rock) is not a suitable material for safety-related plant structures. However, the applicant stated in SSAR Section 2.5.4.7.1 that some safety-related structures (excluding the reactor containment building) may be founded on the Zone III weathered rock, Zone IIB saprolite, or improved Zone IIA saprolite. In response to RAI 2.5.4-7, the applicant noted that the statement in SSAR Section 2.5.4.7.1 is correct, and therefore it will delete the statement in SSAR Section 2.5.1.2.6. The applicant emphasized that only improved Zone IIA saprolite is appropriate for certain safety-related structures (see RAI 2.5.4-11 below). To compute the response of the improved Zone IIA saprolite to dynamic loading, the applicant computed the shear wave velocity through the improved soil based on this increase in stiffness. Profile (b) of SSAR Figure 2.5-62 shows these computed shear wave velocities and the unimproved Zone IIA shear wave velocities. This profile also shows the shear wave velocity values interpreted in SSAR Appendix 2.5.4B from the CPT-825 downhole seismic tests at a depth of 52 ft during the ESP subsurface exploration program. The applicant interpreted the subsurface materials below a depth of 30 ft in the CPT log as a silty sand and sandy silt mix. These could be either Zone IIB saprolitic sands or Zone III weathered rock (or both). From depths between 30 and 40 ft, the design profile uses the shear wave velocity for the Zone IIB saprolite from SSAR Table 2.5-45 (1600 ft/s), which is very close to the 1650 ft/s measured in the CPT-825 downhole seismic test. From depths of 40 to 55 ft, the design profile uses the shear wave velocity for the Zone III weathered rock from SSAR Table 2.5-45 (2000 ft/s). This is close to the mean of the two CPT-825 downhole seismic velocities measured in this zone, as shown in SSAR Figure 2.5-62, Profile (b). The applicant assumed Zone III-IV to extend from depths of 55 to 70 ft. Shear wave velocity for this rock is 3300 ft/s, derived from several values measured in the downhole seismic test performed adjacent to boring B-802 and from elastic modulus values from unconfined compression tests (SSAR Section 2.5.4.2.5).

Variation of Shear Modulus and Damping with Strain

Figure 2.5.4-5, reproduced from SSAR Figure 2.5-63, shows normalized shear modulus reduction curves, which are taken from research reports referenced in SSAR Section 2.5.4.

Curve 1 in this figure represents the Zone IIA saprolite (both unimproved and improved). This modulus reduction curve is the average of (1) the 1970 Seed and Idriss (Ref. 167, SSAR Section 2.5) average curve for sand and (2) five curves (from a 1993 EPRI report (Ref. 170, SSAR Section 2.5)) that take into account several factors, including reference strain and effective vertical stress. One of the five EPRI curves is a low-plasticity clay curve to account for the cohesive component of the Zone IIA saprolite. Curve 2 in SSAR Figure 2.5-63 represents the Zone IIB saprolite and is the modulus reduction curve recommended by Seed, et al. (Ref. 168, SSAR Section 2.5) for gravels, based on tests of four different gravels and crushed stone samples. The Zone IIB saprolite contains the relict structure of the parent rock. Since this contains up to 50 percent of core rock remaining in the saprolite, the applicant stated that it would behave more like a gravel or crushed stone than a sand.

The applicant stated that solid rock does not exhibit the strain-softening characteristics of soil. Thus, the Zone III-IV rock has no modulus reduction curve. However, at some stage of weathering, rock becomes sufficiently decomposed to exhibit modulus reduction. The applicant considered Zone III moderately to severely weathered rock as falling into this sufficiently weathered state. Curve 3 in SSAR Figure 2.5-63 was developed for mudstone (a soft rock) with a shear wave velocity of 1500 ft/s (Ref. 169, SSAR Section 2.5). SSAR Section 2.5.4.7.1 shows that Zone III has a shear wave velocity of 2000 ft/s. The applicant stated that when mudstone Curve 3 is used for shear modulus input in the soil/rock column amplification/

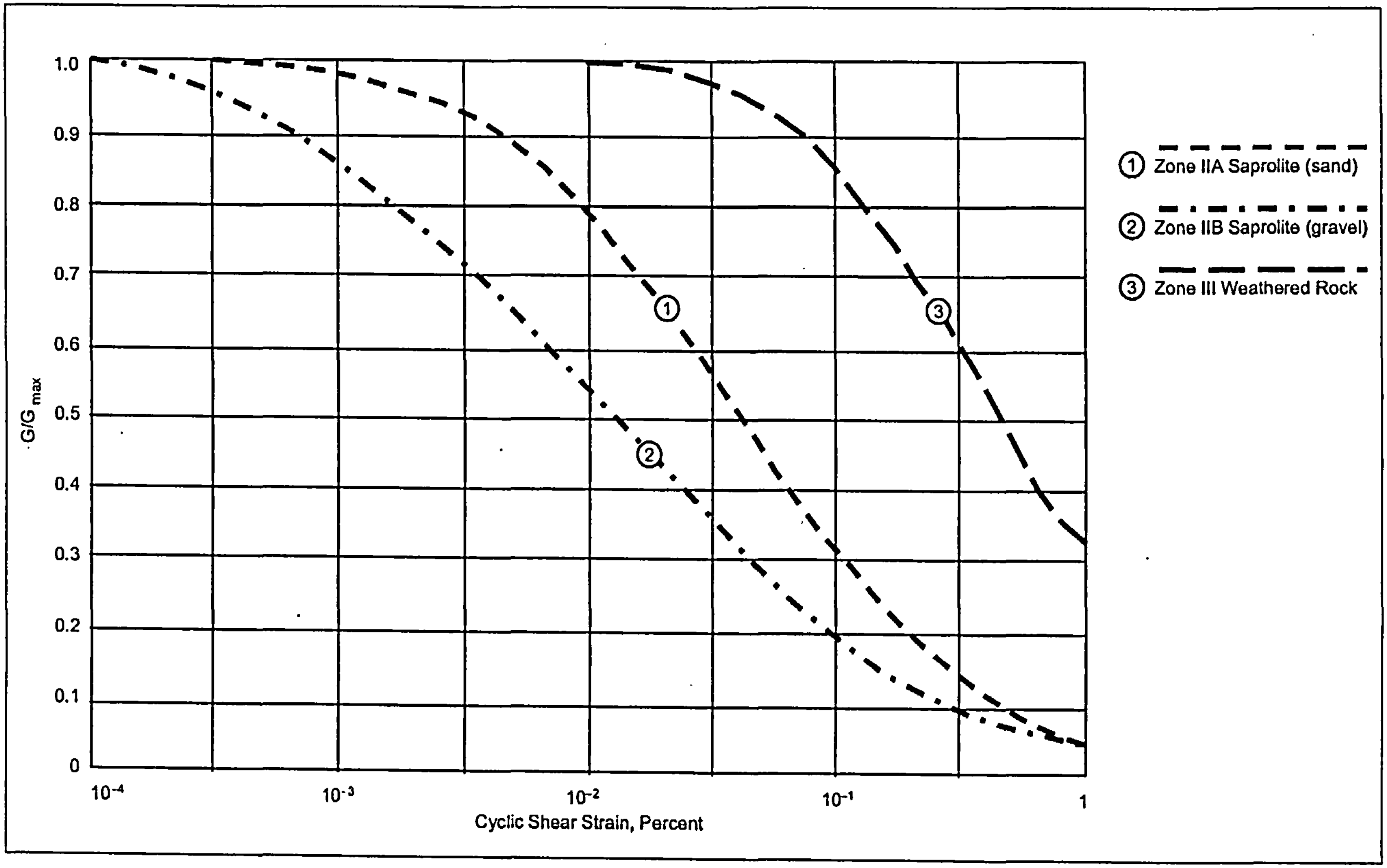


Figure 2.5.4-5 Variation of normalized shear modulus with cycle shear strain

attenuation analysis for the Zone III weathered rock, the shear modulus attenuation is significantly less than that exhibited by the sand and gravel curves.

In SSAR Section 2.5.4.7.1, the applicant stated the following:

> When the specific locations of safety-related structures are determined, if structures such as the diesel generator building and/or certain tanks are founded on saprolite or weathered rock, samples of foundation soils from those locations would be tested to determine location-specific shear modulus degradation relationships.

Figure 2.5.4-6, reproduced from SSAR Figure 2.5-64, plots the variation of the equivalent damping ratio of saprolite and weathered rock as a function of cyclic shear strain.

Curve I in SSAR Figure 2.5-64 represents the Zone IIA saprolite (both unimproved and improved). The applicant stated that this damping ratio versus cyclic shear strain curve is the average of (1) the Seed and Idriss (Ref. 167, SSAR Section 2.5) average curve for sand and (2) seven curves from Reference 170 that take into account several factors including reference strain and effective vertical stress. One of these seven curves is a low-plasticity clay curve to account for the cohesive component of the Zone IIA saprolite. Curve II in SSAR Figure 2.5-64 represents the Zone IIB saprolite. The applicant used the Seed et al. (Ref. 168, SSAR Section 2.5) curve for gravels. Curve III in SSAR Figure 2.5-64 represents the Zone III weathered rock. The applicant stated that it derived this curve by comparing Curve 3 in SSAR Figure 2.5-63 with Curves 1 and 2 in SSAR Figure 2.5-63 and applying the differences proportionally to SSAR Figure 2.5-64. The applicant stated that the damping ratio of the Zone III-IV rock does not vary with cyclic shear strain. However, since this rock has some intrinsic damping properties, the applicant used a damping ratio of 2 percent.

In RAI 2.5.4-8, the staff asked the applicant to provide its basis for the selected modulus reduction and damping ratio curves for Zones IIA, IIB, and III. In its response, the applicant stated that it used the 1993 EPRI report (Ref. 170, SSAR Section 2.5), where applicable, as the basis for the shear modulus reduction and damping ratio curves.

In RAI 2.5.4-8(c), the staff asked the applicant to explain its use of a damping ratio of 2 percent for the Zone III-IV rock. In its response, the applicant stated that the damping ratio for rock varies from site to site depending on the various factors, including the mineral composition of the rock, the integrity and fissuring of the rock mass, and the level of shear deformation in the rock formation. According to the applicant, damping ratios for rock are generally between 0.5 to 4.5 percent. The applicant selected 2 percent for the Zone III-IV rock based on engineering judgment and past experience. To determine the sensitivity of the selected damping ratio, the applicant reran its analysis using damping ratios of 0.5, 1.0, and 5.0 percent. The results show only a slight difference in the peak acceleration for the different damping ratios.

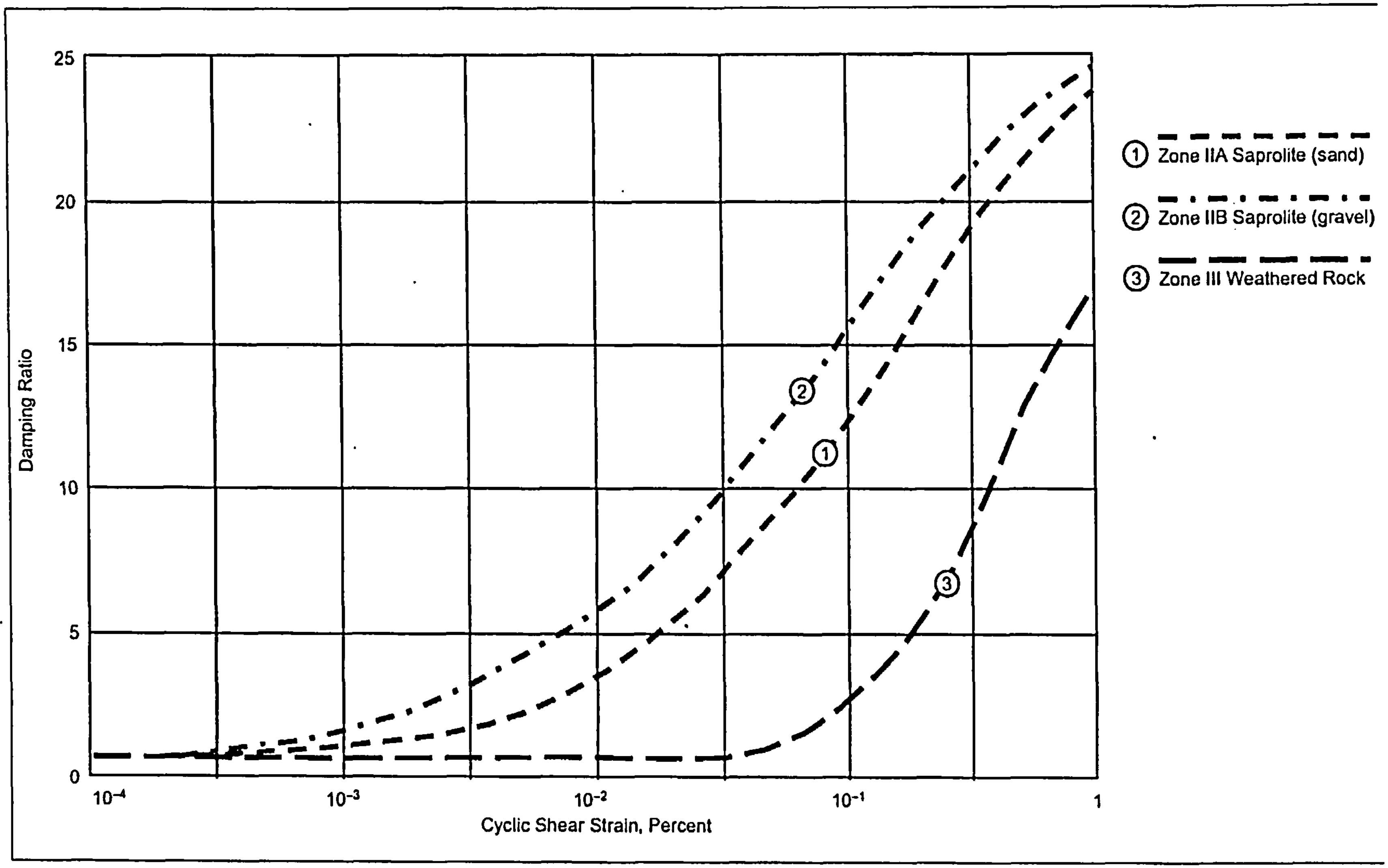


Figure 2.5.4-6 Variation of damping ratio with cyclic shear strain

Site-Specific Acceleration-Time Histories

The applicant developed two single horizontal-component acceleration time histories, which are compatible with the low- and high-frequency response spectra developed from the two controlling earthquakes and PSHA hazard curves. The applicant used these two acceleration time histories in the soil column amplification analysis described below.

In RAI 2.5.4-9(a), the staff asked the applicant to describe its method for developing the site-specific acceleration time histories. In its response, the applicant stated that it selected two horizontal-component acceleration time histories which it then matched to the low- and high-frequency response spectra from the two controlling earthquakes. The applicant then used these spectrum-compatible time histories for the site response analysis. In RAI 2.5.4-9(b), the staff asked the applicant to further describe the method it used for the development of the soil column amplification/attenuation analysis. In its response, the applicant stated that it used the SHAKE2000 computer program to compute the site dynamic responses for the four soil and rock profiles described in SSAR Section 2.5.4.7.1. The applicant provided the input soil parameters, the depth at which the hard rock ground motion was input (70 ft), and information on the number of iterations to compute the strain-compatible modulus and damping values for the SHAKE analysis. In RAIs 2.5.4-9(c) and (d), the staff asked the applicant to further describe the four soil profiles and how the analysis accounted for the variability of the soil properties. In response to RAIs 2.5.4-9(c) and (d), the applicant provided the soil properties for each of the four profiles and described the values that were varied in the analysis. The applicant stated that the shear wave velocity (V_s) and G_{max}, which is derived from V_s, have the most impact on the amplification/attenuation analysis. The applicant showed response spectra for different levels of G_{max} (67 to 150 percent). In RAI 2.5.4-9(e), the staff asked the applicant to justify its use of the mean 10^{-4} uniform hazard spectrum as the input rock motion. In response to RAI 2.5.4-9(e), the applicant stated that it initially used a time history matched to the mean 10^{-4} uniform hazard spectrum; however, it later revised this approach to use time histories that match the low- and high-frequency response spectra calculated from the two controlling earthquakes.

Soil Column Amplification/Attenuation Analysis

The applicant used the SHAKE2000 computer program to compute the site dynamic responses for the soil and rock profiles, described in SSAR Section 2.5.4.7.1. The analysis, performed in the frequency domain, used the two acceleration time histories briefly described in the previous section and in SSAR Section 2.5.2. The analysis used (1) the low-frequency controlling earthquake time history with a peak acceleration of 0.21g and (2) the high-frequency controlling earthquake time history with a peak acceleration of 0.43g.

Table 2.5-46 of the SSAR shows the zero period acceleration (ZPA) results for the SHAKE2000 analysis for the four soil profiles, given in SSAR Section 2.5.4.7.1. The ZPA results for soil Profile 1, with 30 ft of unimproved Zone IIA saprolite, are 0.91g for the high-frequency case and 0.46g for the low-frequency case. The applicant also determined the ZPA results for the four soil profiles using a G_{max} value that was 150 percent of the average G_{max} value. Using these higher G_{max} values, the applicant obtained ZPA values of 0.99g and 0.57g for the high-and low-frequency cases, respectively. As described in SSAR Section 2.5.4.8 and below, the applicant applied these amplified accelerations in the liquefaction evaluation of soils.

2.5.4.1.8 Liquefaction Potential

Soil liquefaction is a process by which loose, saturated, granular deposits lose a significant portion of their shear strength because of pore pressure buildup resulting from cyclic loading, such as that caused by an earthquake. Soil liquefaction can occur, leading to foundation bearing failures and excessive settlements, when (1) the ground acceleration is high, (2) soil is saturated (i.e., close to or below the water table), and (3) the site soils are sands or silty sands in a loose or medium-dense condition. The applicant stated that the ESP site meets the first criterion, and the second criterion applies in many areas of the NAPS site; however, the third criterion, involving the type and density of the soil, is much less clearly applicable. According to the applicant, the Zone IIB soils are extremely dense. The Zone III weathered rock has over 50 percent core stone and has typically been sampled by rock coring. As such, neither of these materials meets the loose or medium-dense criterion, and neither has liquefaction potential. The applicant stated that any needed structural fill would be a well-compacted, well-graded crushed stone that is not liquefiable. Reasoning that neither the Zone IIB soils nor the Zone III weathered rock are susceptible to liquefaction, the applicant only discussed the liquefaction potential of the Zone IIA saprolitic soil.

The applicant stated that there is no historical evidence that Zone IIA saprolitic soils have undergone liquefaction at the ESP site. Attachment 4 to Appendix 3E to the UFSAR indicates that examination of the structure and fabric of the material "leads to the conclusion that the saprolite is not susceptible to liquefaction." Despite its apparent low potential for liquefaction, the Zone IIA saprolite at the NAPS site has been the subject of several previous liquefaction analyses. SSAR Section 2.5.4.8.2 examines these analyses in view of the accelerations assumed for the ESP. In addition, the applicant performed a liquefaction analysis, summarized below, on potentially liquefiable samples obtained from the recent ESP exploration program.

Effect of Soil Structure and Fabric on Liquefaction Potential

SSAR Section 2.5.4.8 describes the soil structure and fabric of the saprolite. The applicant stated that the fabric of the saprolite is similar to that of its parent rock, a biotitic [mineral in mica group] quartz gneiss. According to the applicant, there is a strong foliation in the saprolite and the fabric is strongly anisotropic. The applicant contrasted the highly foliated and anisotropic fabric of the saprolite with that of an alluvial- or marine-deposited sand. The applicant stated that sand shows no foliation and no interlocking of grains. In addition, a thin section of sand shows a well-developed void network unlike that of saprolite. The applicant concluded by stating that the geometric interlocking of the grains and the lack of a void network indicates that the saprolite could not liquefy. Despite this conclusion, the applicant analyzed the potential of the saprolite to liquefy under both the high-frequency and low-frequency input bedrock motions.

Acceptable Factor of Safety Against Liquefaction

According to RG 1.198 (Ref. 172, SSAR Section 2.5), a factor of safety (FS) of 1.1 against liquefaction is considered low, FSs of 1.1 to 1.4 are considered moderate, and an FS of 1.4 is considered high. The Committee on Earthquake Engineering (Ref. 173, SSAR Section 2.5) states that there is no general agreement on the appropriate margin (factor) of safety. If the design earthquake ground motion is regarded as reasonable, an FS of 1.33 to 1.35 is suggested as adequate. However, when the design ground motion is excessively conservative, the Committee notes that engineers are content with an FS only slightly in excess of unity. The SSE at rock for the existing NAPS units has a maximum acceleration of 0.12g, amplified to 0.18g in the soil. The seismic margin maximum acceleration in soil (Ref. 174, SSAR Section 2.5) is 0.30g. The maximum ESP acceleration at hard bedrock rock is 0.39g, amplified at the unimproved soil surface to 0.99g (SSAR Table 2.5-46). Based on these results, which the applicant determined to be very conservative, the applicant considers an FS of 1.1 to be adequate for the Zone IIA soils at the ESP site.

Previous Liquefaction Analyses

Virginia Power performed a detailed liquefaction analysis at the NAPS site in December 1994 for a seismic margin assessment (Ref. 174, SSAR Section 2.5). For the analysis, Virginia Power used a maximum acceleration of 0.3g, a magnitude of 6.8, and three different approaches to assess the potential for soil liquefaction. For the first approach, Virginia Power used the Seed and Idriss simplified procedure (Ref. 175, SSAR Section 2.5), with some modifications to account for the age of the saprolites and for the overconsolidated nature of the saprolites. The resulting FSs range from 1.54 to 3.51. For the second approach, Virginia Power used a threshold strain analysis (Ref. 177, SSAR Section 2.5), with an average shear wave velocity in the saprolite of 950 ft/s, resulting in an FS just under 3.0. For the third approach, Virginia Power used the results of the 15 stress-controlled cyclic triaxial tests, described in SSAR Section 2.5.4.2.4. The FSs against liquefaction range from 1.51 to 1.99 for the SWR facilities (pump house, valve house, tie-in vault, and service water lines). Analysis of the SWR embankment gave FS values ranging from 0.91 to 3.61, with an average of more than 1.5. The applicant stated that the few values below 1 occurred in localized zones and concluded that overall FSs across the embankment are well within acceptable limits. A consistent pattern of low FSs across the foundation would indicate that significant movements of the embankments would occur.

Liquefaction Analyses Performed for ESP

Based on the deaggregation of the PSHA in SSAR Section 2.5.2, the applicant used two earthquakes in the liquefaction analysis. The low-frequency earthquake has a magnitude of 7.2 and a bedrock acceleration of 0.21g. The high-frequency earthquake has a magnitude of 5.4 and a bedrock acceleration of 0.43g. SSAR Table 2.5-46 shows the ZPA values for the four soil/rock profiles described in SSAR Section 2.5.4.7.1. Since the Zone IIB saprolite and the Zone III weathered rock are not liquefiable, the liquefaction analysis did not consider Profiles 2 and 3 in SSAR Table 2.5-46. In Profile 4, the Zone IIA saprolite is improved (i.e., this would be the profile for any safety-related structures founded on the Zone IIA saprolite). The applicant stated that the soil would be improved sufficiently to ensure that the improved soil has an FS greater than or equal to 1.1 using the SSE ground motion. In Profile 1, the Zone IIA saprolite (upper 30 ft) is not improved. Thus, the applicant considered only Profile 1 for the liquefaction analysis. As noted above, the applicant used PGA values of 0.57g and 0.99g for the liquefaction analyses, which are described below.

The applicant performed a liquefaction analysis of each sample of Zone IIA saprolite, obtained by SPT sampling during the ESP subsurface investigation, to determine the FS against liquefaction. The applicant also analyzed the CPT results following the method proposed by Youd, et al. (Ref. 178, SSAR Section 2.5). The applicant stated that, using PGA values of 0.57g and 0.99g, the analysis of the SPT results gave FS values against liquefaction of greater than 1.1, except in one case. The applicant's analysis of the CPT results shows 5-foot thick zones in two CPTs and a 22-foot thick zone in another CPT, where the FS values against liquefaction are less than 1.1, implying that these soil zones would liquefy.

The applicant also performed a liquefaction analysis using shear wave velocity criteria incorporating the design values of shear wave velocity shown in SSAR Figure 2.5-62 and tabulated in SSAR Table 2.5-46. To correct the shear wave velocity values for overburden pressure, the applicant used the method outlined in Youd, et al. (Ref. 178, SSAR Section 2.5). The resulting values all fell into the no-liquefaction zone in Figure 9 of Reference 178. However, when the applicant used the lower bound values of the shear wave velocity, shown in SSAR Table 2.5-45, in the liquefaction analysis, most of the top 20 ft of Profile 1 fell into the liquefaction zone as shown in Figure 9 of Reference 178.

The applicant also determined the liquefaction-induced dynamic settlement using the method outlined in Tokimatsu and Seed (Ref. 179, SSAR Section 2.5). The maximum estimated dynamic settlement of the Zone IIA saprolite caused by earthquake shaking is about 5 in.

The applicant concluded the following concerning the liquefaction potential of the soils at the ESP site:

- Only the Zone IIA saprolites fall into the gradation and relative density categories where liquefaction would be considered possible.

- The structure, fabric, and mineralogy of these saprolites lower the potential for liquefaction very substantially.

- For a conventional liquefaction analysis, an FS of 1.1 is adequate, based on the conservative estimate of the ESP design seismic acceleration.

- A liquefaction analysis of the ESP SPT samples using the low- and high-frequency ESP seismic parameters gave FS values greater than 1.1 for all except one SPT result.

- A liquefaction analysis of the ESP CPT measurements using the low- and high-frequency ESP seismic parameters indicated an approximately 22-ft-thick zone and two 5-ft-thick zones where the FS against liquefaction was less than 1.1.

- A liquefaction analysis of the shear wave velocity profile indicated no liquefaction when the average shear wave velocity values were used. Using lower shear wave velocity values resulted in liquefaction of most of the top 20 ft.

- Estimated dynamic settlements caused by earthquake shaking are about 5 in.

Based on the above analysis, the applicant concluded that some of the Zone IIA saprolitic soils have a potential for liquefaction based on the low- and high-frequency ESP seismic parameters. The applicant stated that the liquefaction analysis did not take into account the beneficial effects of the fabric of the saprolitic soil. The applicant concluded by stating that, if safety-related structures are founded on the Zone IIA saprolitic soils, these soils would be improved to reduce potential settlements and to ensure that the FS against liquefaction is equal to or greater than 1.1.

In RAI 2.5.4-10, the staff asked the applicant to describe how it varied the significant soil properties and seismic input values for each of the different liquefaction analyses. In addition, the staff asked the applicant to provide a sample liquefaction analysis. In its response, the applicant stated that it based its liquefaction analyses on the work of Youd et al. (Ref. 178, SSAR Section 2.5). For each of the three different analyses, the applicant varied G_{max}, the peak earthquake acceleration, and the earthquake magnitude.

2.5.4.1.9 Earthquake Design Basis

SSAR Section 2.5.4.9 refers to SSAR Section 2.5.2.6, which derives and discusses the SSE for the ESP site in detail. Section 2.5.2 of this SER contains the staff's review of that information.

2.5.4.1.10 Static Stability

SSAR Section 2.5.4.10 describes the allowable bearing capacities for each subsurface zone as well as the estimated settlement for each zone. The applicant stated that reactor containment buildings at the ESP site would be founded on Zone III-IV or Zone IV bedrock. Depending on the location of these buildings, the top of this bedrock could occur below the level of the shallower reactor designs. In such cases, the applicant stated that it would excavate to sound bedrock and pour lean concrete up to the bottom of the reactor foundation. In some locations, the top of Zone III-IV or Zone IV bedrock is found close to or even above the planned plant grade. In such cases, safety-related structures would be founded on bedrock or on a thin layer of lean concrete or compacted structural fill on the bedrock. In other locations, sound bedrock is relatively deep. In this case, the applicant stated that safety-related structures (excluding the reactors) may be founded on the Zone III weathered rock, Zone IIB saprolite, or Zone IIA saprolite. The following sections on bearing capacity and settlement focus on this latter situation. (As noted in SSAR Section 2.5.4.10.2, the applicant stated that it would improve any Zone IIA saprolites supporting safety-related structures to reduce potential settlement.)

<u>Bearing Capacity</u>

Table 2.5-47 in the SSAR gives the allowable bearing capacity values for each zone. The applicant stated that it based the Zone IIA allowable bearing capacity value of 4 ksf (4000 lb/ft^2) on Terzaghi's bearing capacity equations modified by Vesic (Ref. 180, SSAR Section 2.5). According to the applicant, the analysis considers the effective strength parameters for the coarse-grained material and both the undrained and effective strength parameters for the fine-grained material given in SSAR Table 2.5-45. As discussed in SSAR Section 2.5.4.10.2, settlement considerations usually dominate when this material is used for supporting

capacity exceeds the maximum bearing pressures of many of the reactor designs considered in the application, the containment (reactor) buildings would not be founded on the Zone III weathered rock. The bedrock in Zones III-IV and IV has an unconfined compressive strength of 4 ksi (576 ksf) and 12 ksi (1728 ksf), respectively (SSAR Table 2.5-45). The applicant stated that allowable bearing capacities of these materials are much higher than any applied structure bearing pressure. In addition, the applicant stated that, if excavation during construction reveals any weathered or fractured zones at the foundation level, it would excavate such zones and replace them with lean concrete. The allowable values of the bearing capacity of 80 and 160 ksf for Zone III-IV and IV rock, shown in SSAR Table 2-5.47, are presumptive values based on various building codes for moderately weathered to fresh foliated rock.

In RAI 2.5.4-11, the staff asked the applicant to provide further details concerning its calculation of the bearing capacities of the soil and rock underlying the ESP site. In its response, the applicant provided a sample calculation for the staff to review. In addition, the applicant stated that the maximum bearing pressure from the containment building foundation is 15 ksf, which is only a fraction of the allowable bearing capacity of the bedrock (Zone III-IV is 80 ksf and Zone IV is 160 ksf).

<u>Settlement Analysis</u>

Peck et al. (Ref. 182, SSAR Section 2.5) indicates that total settlement should be limited to 2 in., and differential settlement to 0.75 in., for the large mat foundations that support major power plant structures. According to Peck, for footings that support smaller plant components, the total settlement should be limited to 1 in. and the differential settlement to 0.5 in.

Settlement of Materials in Zones IIB, III, III-IV, and IV

The applicant stated that the settlement of the materials in Zones IIB, III, III-IV, and IV is essentially elastic. The applicant analyzed a large foundation with an assumed size of 150 ft by 300 ft (e.g., a turbine building foundation) for settlement assuming a soil profile of 20 ft for Zone IIB, underlain by 30 ft of Zone III, 50 ft of Zone III-IV, and 400 ft of Zone IV. The applicant used the high-strain elastic modulus values given in SSAR Table 2.5-45 as the stiffness values. The applicant found that the foundation has an average bearing pressure of 6 ksf. The computed total settlement of this structure is less than 0.5 in.

Settlement of Zone IIA

The applicant stated that Virginia Power recorded larger settlements than expected (i.e., 4.6 in.) beneath the SWR pump house of the existing units because of the weight of the pump house and the 30 ft of embankment fill that was built up around it. This settlement occurred over a 30-month period. The in-situ soil that settled beneath the pump house consists of about 65 ft of Zone IIA, mainly micaceous sandy silt. The applicant stated that the primary cause of this fairly large settlement appears to be the 5 to 20 percent mica content of these saprolites, along with a significant portion of low-plasticity clay minerals. The applicant concluded that, although the settlement of the SWR pump house is an extreme case and resulted from several factors, the potential for excessive settlement of the Zone IIA saprolite makes this material unsuitable to support any safety-related structure without ground improvement.

2.5.4.1.11 Design Criteria

SSAR Section 2.5.4.11 summarizes the geotechnical design criteria. In addition, various sections of the SSAR cover other applicable design criteria. SSAR Section 2.5.4.8 specifies that the acceptable FS against liquefaction of site soils should be 1.1. SSAR Section 2.5.4.10 presents bearing capacity and settlement criteria. SSAR Table 2.5-47 provides allowable bearing capacity values for the site subsurface materials. Generally acceptable total and differential settlements are limited to 2 in. and 0.75 in., respectively, for mat foundations and 1 in. and 0.5 in., respectively, for footings. SSAR Section 2.5.5.2 specifies that the minimum acceptable long-term static FS against slope stability failure is 1.5. SSAR Section 2.5.5.3 specifies that the minimum acceptable long-term seismic FS against slope stability failure is 1.1.

In RAI 2.5.4-12, the staff asked the applicant to explain why it did not provide design criteria pertaining to structural design. In its response, the applicant stated that structural criteria such as allowable wall rotation and FSs against structure sliding and overturning are not site specific and thus are not included in SSAR Section 2.5. The applicant stated that a COL application would describe these structural criteria.

2.5.4.1.12 Techniques to Improve Subsurface Conditions

SSAR Section 2.5.4.12 outlines several ground improvement techniques that would be implemented before the Zone IIA saprolitic soils could be used to support safety-related foundations. As its primary choice for reducing the settlement potential of the Zone IIA saprolitic soils, the applicant considered vibro-stone columns. According to the applicant, vibro-stone columns have several advantages, including reduction of settlement, improvement of bearing capacity, and reduction of liquefaction potential. The vibro-stone column method involves the insertion of a vibratory probe (aided by water jets or compressed air) into the base of the stratum that needs improvement. Crushed stone is poured into the annulus and is densified by the vibrator. This process results in a series of highly compacted stone columns, typically about 3 ft in diameter, spaced on about 5- to 8-ft centers.

2.5.4.2 Regulatory Evaluation

SSAR Section 2.5.4 describes the applicant's evaluation of the stability of the subsurface materials and foundations at the ESP site. In SSAR Section 1.8, the applicant stated that it developed the geological, geophysical, and geotechnical information used to evaluate the stability of the subsurface materials in accordance with the requirements of 10 CFR 100.23. The applicant applied the guidance of RS-002, RG 1.70, DG-1105 (which has been superseded by RG 1.198 since the applicant submitted the SSAR), RG 1.132; and RG 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants."

In its review of SSAR Section 2.5.4, the staff considered the regulatory requirements in 10 CFR 100.23(c) and 10 CFR 100.23(d)(4). According to 10 CFR 100.23(c), applicants must investigate the engineering characteristics of a site and its environs in sufficient scope and detail to permit an adequate evaluation of the proposed site. Pursuant to 10 CFR 100.23(d)(4), applicants must evaluate siting factors such as soil and rock stability, liquefaction potential, and natural and artificial slope stability. Section 2.5.4 of RS-002 provides specific guidance concerning the evaluation of information characterizing the stability of subsurface materials, including the need for geotechnical field and laboratory tests as well as the geophysical investigations.

2.5.4.3 Technical Evaluation

This section provides the staff's evaluation of the geophysical and geotechnical investigations carried out by the applicant to determine the static and dynamic engineering properties of the materials that underlie the ESP site. The technical information presented in SSAR Section 2.5.4 resulted from the applicant's field and laboratory investigations performed for the ESP. The applicant intended its additional field and laboratory investigations to confirm the large volume of geotechnical data developed by Virginia Power for the existing units and the abandoned Units 3 and 4 within the ESP site area. The applicant used the subsurface material properties from its field and laboratory investigations to evaluate the liquefaction potential, bearing capacity, and potential for settlement.

Through its review of SSAR Section 2.5.4, the staff determined whether the applicant demonstrated the stability of the subsurface materials under both static and dynamic conditions. The staff also reviewed the applicant's field and laboratory investigations used to determine the geotechnical properties of the soil and rock underlying the ESP site. In addition, the staff observed some of the applicant's onsite borings and field explorations, performed in November and December 2002, to determine whether the applicant followed the guidance in RG 1.132.

2.5.4.3.1 Geologic Features

SSAR Section 2.5.4.1 references SSAR Sections 2.5.1.1 and 2.5.1.2 for a description of the regional and site geology. Section 2.5.1.3 of this SER presents the staff's evaluation of these two sections.

2.5.4.3.2 Properties of Subsurface Materials

The staff focused its review of SSAR Sections 2.5.4.2 and 2.5.4.3 on the applicant's description of (1) subsurface materials, (2) field investigations, (3) laboratory testing, and (4) static and dynamic engineering properties of the ESP site subsurface materials.

Normally, an applicant performs a complete field investigation and sampling program to evaluate the engineering properties and stability of the soil and rock underlying the site. However, since the applicant relied on Virginia Power's previous field and laboratory investigations for the existing and abandoned units, it used its ESP investigations to confirm previously established soil and rock properties. In RAI 2.5.4-1, the staff asked the applicant to provide its basis for concluding that the subsurface conditions in the southeast portion of the ESP footprint (an area of about 500 ft by 1000 ft, in which there are no borings) do not materially differ from conditions in adjacent areas, where borings were made. In response to RAI 2.5.4-1, the applicant stated that the North Anna site is underlain by a consistent geologic profile, which extends to a depth of several thousand feet. The applicant stated that the 145 borings performed throughout the North Anna site (including 7 borings for the ESP) indicate a consistent overall subsurface profile, with expected variations in the thickness of the various strata. As such, the applicant concluded that the southeast portion of the ESP footprint (see SER Figure 2.5.4-3) should be similar to the rest of the site. Because of the consistency of the soil and rock engineering properties across the NAPS and ESP sites, the staff has determined that Virginia Power's past investigations, combined with the ESP applicant's explorations, are adequate to characterize the subsurface conditions in the locations where data were collected. Further, based on its review of the NAPS and ESP borings, the staff has determined that a consistent geologic profile underlies the North Anna ESP site. The staff concludes, therefore, that the uncharacterized southeast portion of the site should have subsurface conditions similar to those found at the rest of the site. Accordingly, the staff concludes that the applicant has provided an adequate description of the subsurface profile. The applicant's commitment to perform additional borings to confirm its conclusions regarding engineering properties and the stability of soil and rock underlying future plant SSCs is **COL Action Item 2.5-1.**

In RAI 2.5.4-3, the staff asked the applicant to describe how it integrated Virginia Power's site investigations for the SWR and the ISFSI with its field investigations for the ESP site. In its response, the applicant stated that the SWR and ISFSI borings are as close to the ESP area as any other borings and disclose the same subsurface profile displayed by the other borings at the North Anna site (see SER Figure 2.5.4-3). In addition, the applicant stated that it used some of the SWR and ISFSI borings, which are close to the southeast corner of the ESP footprint, noted in RAI 2.5.4-1, to help characterize the ESP area. Because of the consistency of the soil and rock engineering properties across the NAPS and ESP sites, the staff has determined that Virginia Power's past investigations, combined with the ESP applicant's explorations, are adequate to characterize the subsurface conditions in the locations where data were collected.

In RAI 2.5.4-4, the staff asked the applicant to explain how the total thickness of the soil layers sampled at the ESP site (105 ft) is sufficient to characterize the soil properties underlying the site. In its response, the applicant stated that the 138 borings performed previously by Virginia Power for Units 1 and 2 as well as abandoned Units 3 and 4 characterize the soils at the North Anna site very well. The applicant stated that the soils in all the borings show the same general subsurface profile and that it used the ESP borings to show that the soil (and rock) profiles in each of the borings fit within the general subsurface profile. Based on the results of the NAPS and ESP borings, the staff has determined that a consistent geologic profile underlies the North Anna ESP site. The staff concludes, therefore, that the applicant adequately sampled the soil underlying the ESP site in order to confirm the results of borings previously performed by Virginia Power.

In RAI 2.5.4-2(a), the staff asked the applicant to describe the extent of severely weathered fracture zones in the Zone III-IV and IV rock that Virginia Power observed during the site investigation for abandoned Units 3 and 4. The applicant observed similarly fractured rock in four of the seven ESP borings. In its response, the applicant provided a table that shows an RQD of less than 25 percent in nine of the borings for abandoned Units 3 and 4. The applicant noted that most of the rock for the low RQD intervals (less than 10 percent) is only 1 to 2 ft thick. In RAI 2.5.4-2(b), the staff asked the applicant to describe the impact of these fractured rock zones on the suitability of the site to host safety-related structures. In its response, the applicant stated the following:

> As noted in these SSAR sections, any weathered or fractured zones encountered at foundation level would be excavated and replaced with lean concrete. If such zones exist below sound rock beneath the foundation, they

would have no impact on the stability of the foundation, since these zones are typically only 0.5 to 1-foot thick, and are confined within an unfractured rock mass with strengths of 4,000 to 12,000 psi (compared to the maximum foundation pressure of just over 100 psi). The foundation itself would consist of a large, thick, highly-reinforced concrete mat that is so stiff that it cannot logically yield.

Multiple borings would be performed at each structure location once the building locations are chosen as part of detailed engineering. These borings would identify whether there are any thicker fracture zones beneath the foundation than those encountered in the ESP borings and in the abandoned Units 3 and 4 borings. If any thicker zones are found, analysis would be performed to identify their impact on foundation stability. If they are close enough to the foundation to potentially impact stability, they would be excavated and replaced with lean concrete.

In its response to RAI 2.5.4-2, the applicant stated its commitment to excavate and replace with lean concrete any weathered or fractured zones found at the foundation level, and the staff proposes to include a condition in the ESP to require such activities (Permit Condition 2.5-1). The replacement of fractured rock with lean concrete is well understood and commonly done to enhance the strength and stability of the rock to support building loads. The excavation of weathered or fractured rock zones and their replacement with lean concrete will ensure the bearing capacity of such zones. The staff concludes that this is adequate to ensure the stability of structures that might be constructed on the proposed site.

In RAI 2.5.4-6, the staff asked the applicant to explain why it did not provide laboratory test results from the borings of subsurface materials over various depth intervals. In response to RAI 2.5.4-6, the applicant stated that the containment (reactor) buildings for the new units would be founded on the Zone III-IV and/or Zone IV metamorphic gneiss bedrock at the North Anna site. Rock coring and testing performed by Virginia Power for Units 1 and 2 gave unconfined compressive strengths for the Zone III-IV and IV rock ranging from 1,000 to 16,300 psi, with a median strength of 6,800 psi. The applicant stated that these rock strengths are typical for this type of rock and more than sufficient to support the maximum containment (reactor) building loads of about 100 psi. The applicant added that, during logging of the rock cores in the field for the ESP investigation, it was apparent that the metamorphic rock is a strong material. The applicant performed tests on the ESP cores sufficient to verify that the rock strengths are similar to or higher than those cores tested for Units 1 and 2. The applicant determined that the median value of the unconfined compressive strengths of the Zone III-IV and IV rock from the ESP investigation is 18,400 psi. Because the applicant verified through rock coring and testing during its ESP investigation that the unconfined compressive strength of the Zone III-IV and IV rock is similar to or higher that the cores tested for Units 1 and 2, the staff concludes that the applicant has adequately sampled the Zone III-IV and IV rock.

Furthermore, the staff concurs with the applicant's conclusion that the strength of the Zone III-IV and IV rock is sufficient to support the load of a containment building.

Based on its review of SSAR Sections 2.5.4.2 and 2.5.4.3 and the applicant's responses to its RAIs, as described above, the staff concludes that the applicant adequately determined the engineering properties of the soil and rock underlying the ESP site through its field and laboratory investigations. In addition, the applicant used the latest field and laboratory methods, in accordance with RGs 1.132 and 1.138, to determine these properties. Accordingly, the staff concludes that the applicant performed field investigation and laboratory testing sufficient to determine the overall subsurface profile as well as the material properties underlying the ESP site. The staff notes that the applicant committed to perform additional investigations once it has selected the building locations. The COL (or CP) applicant would describe these additional investigations in its COL (or CP) application.

2.5.4.3.3 Relationship of Foundations and Underlying Materials

Section 2.5.4.3 in RS-002 directs the staff to compare the applicant's plot plans and the profiles of all seismic Category I facilities with the subsurface profile and material properties. Based on this comparison, the staff can determine if (1) the applicant performed sufficient exploration of the subsurface and (2) the applicant's foundation design assumptions contain adequate margins of safety. The applicant decided to defer providing this information until a CP or COL application is submitted. Submission of a COL or CP applicant's plot plans and the profiles of all seismic Category I facilities for comparison with the subsurface profile and material properties is **COL Action Item 2.5-2.**

2.5.4.3.4 Geophysical Surveys

The staff focused its review of SSAR Section 2.5.4.3 on the adequacy of the applicant's geophysical investigations to determine soil and rock dynamic properties. The applicant performed two crosshole seismic tests, one downhole seismic test, and two CPT seismic tests. The applicant compared the dynamic properties it obtained from these tests with the results from the previous geophysical surveys of the North Anna site performed by Virginia Power.

In RAI 2.5.4-5, the staff asked the applicant to explain why SSAR Table 2.5-45 does not provide shear wave velocities for Zone IIB saprolite and Zone III and III-IV weathered rock. In its response, the applicant stated that SSAR Table 2.5-45 gives average shear wave velocities for Zones IIB, III, and III-IV but does not provide a range of values. In contrast, it gives both average values and a range of shear wave velocity values for Zones IIA and IV. The applicant stated that it provided only average values for Zones IIB, III, and III-IV because the ESP borings did not sample these zones as abundantly as Zones IIA and IV. In response to this RAI, the applicant also provided its method for determining the average shear wave velocity values for Zones IIB (1600 ft/s), III (2000 ft/s), and III-IV (3300 ft/s). Because the applicant used both crosshole and downhole seismic tests, as well as direct and indirect methods, the staff concludes that the applicant has adequately measured the shear wave velocity for each of the soil and rock zones. For those zones (IIB, III, and III-IV) for which the applicant did not obtain so many samples from the ESP borings, the applicant used its laboratory measurements of the soil/rock properties to indirectly determine the shear wave velocities. Accordingly, the staff concludes that the applicant adequately sampled the soil and rock underlying the ESP site in order to determine the consistency of its dynamic properties with those previously obtained by Virginia Power in earlier explorations.

The staff has determined that the applicant used the latest geophysical and geotechnical measurement methods and equipment in accordance with the recommendations of RGs 1.132 and 1.138 to determine the dynamic properties of the soil and rock underlying the site. Based on its review of SSAR Section 2.5.4.4 and the applicant's response to the RAI, described above, the staff concludes that the applicant adequately determined the soil and rock dynamic properties through its geophysical survey of the ESP site.

2.5.4.3.5 Excavation and Backfill

In SSAR Section 2.5.4.5, the applicant provided a general description of (1) the extent (horizontally and vertically) of anticipated safety-related excavations, fills, and slopes, (2) excavation methods and stability, (3) backfill sources and quality control, and (4) control of ground water during excavation. The staff found this general description to be useful. However, the applicant has not selected a reactor design or location within the ESP site, and it did not provide detailed excavation and backfill plans or plot plans and profiles as outlined in Section 2.5.4 of RS-002. Therefore, the staff could not adequately evaluate the applicant's excavation and backfill plans and will await the future submittal of these plans by the ESP holder and/or as part of a COL or CP application. This is **COL Action Item 2.5-3.** The staff notes that, in SSAR Section 2.5.4.5, the applicant stated that it would (1) geologically map future excavations for safety-related structures and (2) evaluate any unforseen geologic features that are encountered. In addition, the applicant stated that it would notify the NRC "when any excavations for safety-related structures are open for their examination and evaluation." The staff proposes to include a condition in any ESP that might be issued requiring that the ESP holder and/or an applicant referencing such an ESP perform geologic mapping of future excavations for safety-related structures, evaluate any unforseen geologic features that are encountered, and notify the NRC no later than 30 days before any excavations for safety-related structures are open for NRC's examinations and evaluation. This is **Permit Condition 7.**

2.5.4.3.6 Ground Water Conditions

In SSAR Section 2.5.4.6, the applicant provided a general description of (1) ground water measurements and elevations and (2) construction dewatering plans. The staff found this general description to be useful. However, the applicant has not selected a reactor design or location within the ESP site and did not provide an evaluation of ground water conditions as they affect foundation stability or detailed dewatering plans as outlined in Section 2.5.4 of RS-002. Therefore, the staff could not evaluate the ground water conditions as they affect the loading and stability of foundation materials or the applicant's dewatering plans during construction, as well as ground water control throughout the life of the plant. As such, the staff will await the future submittal of these evaluations and plans as part of the COL or CP application. The need to evaluate ground water conditions as they affect foundation stability or detailed dewatering plans is **COL Action Item 2.5-4.**

2.5.4.3.7 Response of Soil and Rock to Dynamic Loading

In its review of SSAR Section 2.5.4.7, the staff focused on the applicant's shear wave velocity design profiles to determine the response of the soil and rock underlying the ESP site to dynamic loading. In addition, the staff reviewed the applicant's modeling of the variation of soil shear modulus and damping with cyclic shear strain. Finally, the staff reviewed the applicant's site dynamic response, which was based on a soil amplification/attenuation analysis using the four soil profiles.

In RAI 2.5.4-7, the staff asked the applicant to reconcile two conflicting statements in SSAR Sections 2.5.4.7.1 and 2.5.1.2.6. The applicant stated in SSAR Section 2.5.1.2.6 that Zone III (weathered rock) is not a suitable material for safety-related plant structures. However, the applicant stated in SSAR Section 2.5.4.7.1 that some safety-related structures (excluding the reactor containment building) may be founded on the Zone III weathered rock, Zone IIB saprolite, or improved Zone IIA saprolite. In response to RAI 2.5.4-7, the applicant stated that the statement in SSAR Section 2.5.4.7.1 is correct and that it will delete the statement in SSAR Section 2.5.1.2.6. The applicant emphasized that only improved Zone IIA saprolite is appropriate for certain safety-related structures only if it is improved (see RAI 2.5.4-11 below). Based on the applicant's clarification in its response to RAI 2.5.4-7, the staff concludes that it is appropriate to consider the construction of safety-related structures on improved Zone IIA, and Zone IIB, and Zone III materials.

In RAI 2.5.4-8, the staff asked the applicant to provide its basis for the selected modulus reduction and damping ratio curves for Zones IIA, IIB, and III materials. In response to RAI 2.5.4-8, the applicant stated that it used the 1993 EPRI report (Ref. 170, SSAR Section 2.5.2), where applicable, as the basis for the shear modulus reduction and damping ratio curves. The staff reviewed the curves that the applicant selected for each of the soil and rock zones to determine whether the applicant based its selection on appropriate criteria, such as grain size, cohesiveness, confining pressure, and shear wave velocity. The staff concludes that the shear modulus and damping curves selected by the applicant were based on appropriate criteria and are suitable for Zone IIA, IIB, and III soil and rock.

In RAI 2.5.4-8(c), the staff asked the applicant to explain its use of a damping ratio of 2 percent for the Zone III-IV rock. In response to RAI 2.5.4-8(c), the applicant stated that the damping ratio for rock varies from site to site depending on various factors, including the mineral composition of the rock, the integrity and fissuring of the rock mass, and the level of shear deformation in the rock formation. According to the applicant, damping ratios for rock are generally between 0.5 to 4.5 percent. The applicant selected 2 percent for the Zone III-IV rock based on engineering judgment and past experience. To determine the sensitivity of the selected damping ratio, the applicant reran its analysis using damping ratios of 0.5, 1.0, and 5.0 percent. The results reveal only a slight difference in the peak acceleration for the different damping ratios. Based on these results, the staff concludes that a damping ratio of 2 percent for the Zone III-IV rock is acceptable.

In RAI 2.5.4-9(a), the staff asked the applicant to describe the method that it used for the development of the site-specific acceleration time histories. In response to RAI 2.5.4-9(a), the applicant stated that it selected two horizontal-component acceleration time histories, which it then matched to the low- and high-frequency response spectra from the two controlling earthquakes. The applicant next used these spectrum-compatible time histories for the site response analysis. In RAI 2.5.4-9(b), the staff asked the applicant to further describe the method it used for the development of the soil column amplification/attenuation analysis. In response to RAI 2.5.4-9(b), the applicant stated that it used the SHAKE2000 computer program to compute the site dynamic responses for the four soil and rock profiles described in SSAR Section 2.5.4.7.1. The applicant provided the input soil parameters, the depth at which the hard rock ground was input (70 ft), and information on the number of iterations to compute the strain-compatible modulus and damping values for the SHAKE analysis. In RAIs 2.5.4-9(c) and (d), the staff asked the applicant to further describe the four soil profiles and how it accounted for the variability of the soil properties in the analysis. In response to RAIs 2.5.4-9(c) and (d), the applicant provided the soil properties for each of the four profiles and an analysis that demonstrated how it varied these properties. The applicant stated that V_s and G_{max}, which is derived from V_s, have the most impact on the amplification/attenuation analysis. The applicant showed response spectra for different levels of G_{max} (67 to 150 percent). In RAI 2.5.4-9(e), the staff asked the applicant to justify its use of the mean 10^{-4} uniform hazard spectrum as the input rock motion. In response to RAI 2.5.4-9(e), the applicant stated that it initially used a time history matched to the mean 10^{-4} uniform hazard spectrum; however, in Revision 3 to its SSAR, it revised this approach to use time histories that match the low- and high-frequency response spectra calculated from the two controlling earthquakes. Because the applicant used both the low-frequency and high-frequency time histories and four different rock/soil profiles and also accounted for the variability in the soil and rock properties, the staff concludes that the applicant accurately determined the dynamic response of the soil and rock underlying the ESP site to the input hard rock ground motion. As a result of RAI 2.5.4-9, the applicant revised portions of SSAR Sections 2.5.4.7 and 2.5.4.8.

Based on its review of SSAR Section 2.5.4.7 and the applicant's responses to the RAIs, as described above, the staff concludes that the applicant adequately determined the response of the soil and rock underlying the ESP site to dynamic loading. The staff notes the applicant's commitment in response to RAI 2.5.4-9 to perform further soil column amplification/attenuation analyses at the COL stage, once it selects specific locations for the nuclear power plant structures. This is **COL Action Item 2.5-5.** The applicant stated that this analysis would involve subsurface investigations to determine actual strata thicknesses and confirm the subsurface material properties at each location.

2.5.4.3.8 Liquefaction Potential

In its review of SSAR Section 2.5.4.8, the staff evaluated the applicant's liquefaction analyses. The staff's review focused on the applicant's conclusion that only the Zone IIA saprolite is susceptible to liquefaction, as well as the various liquefaction analyses and parameter inputs to these analyses. The applicant concluded that soil Profile 1, which has 30 ft of unimproved Zone IIA saprolite, is potentially susceptible to liquefaction in most of the upper portions. The applicant stated that, if safety-related structures are founded on the Zone IIA saprolitic soils, these soils would be improved to reduce any liquefaction potential.

In RAI 2.5.4-10, the staff asked the applicant to describe how it varied the significant soil properties and seismic input values for each of the different liquefaction analyses. In addition, the staff asked the applicant to provide a sample liquefaction analysis. In its response, the applicant stated that it based the liquefaction analyses on the work of Youd et al. (Ref. 178, SSAR Section 2.5). For each of the three different analyses, the applicant varied G_{max}, the peak earthquake acceleration, and the earthquake magnitude. Based on its review of the sample liquefaction analysis, the staff concludes that the applicant used the latest empirical method and adequately varied the significant soil and seismic input parameters in accordance with the guidance provided in RG 1.198, which recommends the Youd et al. method. Therefore, the applicant's liquefaction analyses are acceptable.

Based on its review of SSAR Section 2.5.4.8 and the applicant's response to RAI 2.5.4-10, described above, the staff concludes that the applicant has employed an acceptable methodology to determine the liquefaction potential of the soil underlying the ESP site. Because portions of the Zone IIA saprolite are susceptible to liquefaction, the applicant stated that, if safety-related structures are founded on the Zone II saprolitic soils, these soils would be improved to reduce any liquefaction potential. Accordingly, the staff proposes to include a condition for any ESP that might be issued requiring that the ESP holder and/or an applicant referencing such an ESP improve Zone II saprolitic soils to reduce any liquefaction potential if safety-related structures are to be founded on them. This is **Permit Condition 8.** The applicant described techniques for improving the Zone IIA saprolitic soils in SSAR Section 2.5.4.12.

2.5.4.3.9 Earthquake Design Basis

SSAR Section 2.5.2.6 presents the applicant's derivation of the SSE. Section 2.5.2.3.6 of this SER summarizes the staff's evaluation of the SSE.

2.5.4.3.10 Static Stability

In its review of SSAR Section 2.5.4.10, the staff focused on the applicant's determination of the bearing capacities for each of the soil and rock zones, as well as the applicant's settlement analysis. The applicant presented bearing capacities for each of the soil and rock zones and described how it obtained these results. In addition, the applicant stated that the settlement of a large foundation with an assumed size of 150 ft by 300 ft, underlain by Zone IIB, would be less than 0.5 in.

In RAI 2.5.4-11, the staff asked the applicant to provide further details concerning its calculation of the bearing capacities of the soil and rock underlying the ESP site. In its response, the applicant provided a sample calculation for the staff to review. In addition, the applicant stated that the maximum bearing pressure from the containment building foundation is 15 ksf, which is only a fraction of the allowable bearing capacity of the bedrock (Zone III-IV is 80 ksf and Zone IV is 160 ksf). During its review of the sample bearing capacity calculation, the staff determined that the applicant used the widely accepted bearing capacity formulas developed by Terzaghi (D.P. Coduto, "Foundation Design," 2nd edition, issued 2001). Accordingly, the staff concludes that the applicant adequately determined bearing capacity values for each of the soil and rock zones. In addition, the staff concludes that the bearing capacities of Zones III-IV and IV rock are sufficient to handle the load of a containment building foundation.

Based on its review of SSAR Section 2.5.4.10 as described above, the staff concludes that the applicant provided an adequate preliminary assessment of the static stability of the ESP site. However, as described in RS-002, for the staff to perform a complete review of site static stability, the staff will need a COL or CP applicant to provide an analysis of the stability of all planned safety-related facilities when the locations of the plant structures are finally specified. This analysis should include bearing capacity, rebound, settlement, and differential settlements, as well as lateral loading conditions for all safety-related facilities. Therefore, the staff concludes that the applicant's description of the static stability is adequate to provide assurance of the stability of the ESP site, but the staff needs additional information to support any finding regarding detailed structure-specific stability. The need to provide an analysis of the stability of all planned safety-related facilities, including bearing capacity, rebound, settlement, and differential settlements under deadloads of fills and plant facilities, as well as lateral loading conditions, is **COL Action Item 2.5-6.**

2.5.4.3.11 Design Criteria

In SSAR Section 2.5.4.11, the applicant provided general geotechnical criteria, such as acceptable FSs against liquefaction, allowable bearing capacities, acceptable total and differential settlements, and acceptable FSs against slope stability failure. The applicant did not provide structural design criteria, such as wall rotation, sliding, and overturning.

In RAI 2.5.4-12, the staff asked the applicant to explain why it did not provide design criteria pertaining to structural design. In its response, the applicant stated that structural criteria, such as allowable wall rotation and FSs against structure sliding and overturning, are not site specific and thus are not included in SSAR Section 2.5. The applicant stated that a COL application would describe these structural criteria. Since 10 CFR Part 52, Subpart A, does not require the submission of such information, the staff concludes that the applicant's decision not to include structural design criteria in the ESP applicant is justified.

Based on its review of SSAR Section 2.5.4.11 and the applicant's response to the RAI, the staff concludes that the applicant adequately presented the necessary design criteria for the ESP site. The need to provide design-related criteria that pertain to structural design (such as wall rotation, sliding, and overturning) is **COL Action Item 2.5-7.**

2.5.4.3.12 Techniques to Improve Subsurface Conditions

In SSAR Section 2.5.4.12, the applicant presented a general description of the ground improvement techniques it may employ so that the Zone IIA saprolitic soils could be used to support safety-related foundations. Although this general description was useful to the staff, a COL or CP applicant should provide specific plans for each proposed ground improvement technique it plans to employ so that the staff may determine whether the chosen techniques will ensure that Zone IIA saprolitic soils will be able to support safety-related foundations. This is **COL Action Item 2.5-8.**

2.5.4.4 Conclusions

Based on its review of SSAR Section 2.5.4 and the applicant's responses to the associated RAIs, described above, the staff concludes that the applicant adequately determined the engineering properties of the soil and rock underlying the ESP site through its field and laboratory investigations. In addition, the applicant used the latest field and laboratory methods, in accordance with RGs 1.132, 1.138, and 1.198, to determine these properties. Accordingly, the staff concludes that the applicant performed sufficient field investigations and laboratory testing to determine the overall subsurface profile, as well as the properties of the soil and rock underlying the ESP site. Specifically, the staff concludes that the applicant adequately determined (1) the soil and rock properties through its field investigations and laboratory tests, (2) the response of the soil and rock to dynamic loading, and (3) the liquefaction potential of the Zone IIA saprolitic soils. The staff notes that the applicant committed to perform additional field investigations once it has selected the locations for safety-related structures at the COL stage.

In SSAR Sections 2.5.4.5 (excavation and backfill), 2.5.4.6 (ground water conditions), 2.5.4.10 (static stability), 2.5.4.11 (design criteria), and 2.5.4.12 (techniques to improve subsurface conditions), the applicant did not provide information sufficient for the staff to perform a complete evaluation. In addition, the applicant did not provide any information on the relationship of the foundation and underlying materials (Section 2.5.4.3 in RS-002). Each of the these topics depends on specific information related to building location and design and will be submitted as part of any COL or CP application.

In SSAR Table 1.9-1, the applicant identified three subsurface material properties as ESP site characteristics. The first site characteristic specifies that there is no potential for liquefaction at the ESP site. The applicant demonstrated, in SSAR Section 2.5.4.1.8, that any liquefaction at the ESP site would be limited to the Zone IIA saprolites, and if any safety-related structures are founded on the Zone IIA saprolites, these soils would be improved to reduce potential settlements and to ensure an FS for liquefaction greater than or equal to 1.1. The second site characteristic specifies a minimum bearing capacity value of 15 ksf. The bearing capacities for rock of Zones III and above underlying the ESP site are greater than 15 ksf (see SSAR Table 2.5-45). Finally, the third site characteristic specifies a minimum shear wave velocity of 3500 ft/s for the material underlying the foundation. The applicant stated that the reactor containment would be founded on Zone III-IV or IV bedrock. Because the average shear wave velocity (V_s) of the Zone III-IV bedrock is slightly less (3300 ft/sec) than this postulated PPE value (3500 ft/sec), the COL or CP applicant should determine the V_s of the actual material underlying the foundation for the reactor containment to ensure that V_s equals or exceeds that of the chosen design. This is **COL Action Item 2.5-9.** The staff has reviewed the applicant's suggested site characteristics and plant design parameters related to SSAR Section 2.5.4 for inclusion in an ESP, should the NRC issue one to the applicant. For the reasons set forth above, the staff agrees with the applicant's site characteristics and values.

2.5.5 Stability of Slopes

SSAR Section 2.5.5 presents information on the stability of permanent slopes at the NAPS site. The applicant used previous geological, geophysical, and geotechnical investigations as a basis for determining the stability of the slopes at the site. SSAR Section 2.5.5.1 describes the existing slope characteristics, SSAR Section 2.5.5.2 describes the design criteria and analyses of slope stability, SSAR Section 2.5.5.3 presents information from two sample borings on or close to the slope, SSAR Section 2.5.5.4 states that the slope does not contain compacted fill, and SSAR Section 2.5.5.5 describes a potential new slope that may be excavated at the site.

2.5.5.1 Technical Information in the Application

2.5.5.1.1 Slope Stability Analysis and Design Criteria

Existing Slope Characteristics

SSAR Section 2.5.5.1 describes an existing 2-horizontal to 1-vertical (2h:1v), 55-ft-high slope that descends from north of the SWR down to the south of the existing excavation made for the abandoned NAPS Units 3 and 4. The slope was excavated during construction of NAPS Units 1 and 2 and is made almost entirely of cut material. Since the top of this slope is 200 ft from the top of the SWR embankment, the applicant concluded that any potential instability of the slope would have no impact on the stability of the SWR embankment. However, sloughing or collapse of the slope could impact the new units, depending on their final location.

The NAPS licensee took two slope borings, conducted for the Unit 1 and 2 investigation, close to the area of the slope. As shown in the boring profiles, the soils in the slope consist almost entirely of Zone IIA saprolites. Saprolites are a further stage of weathering beyond weathered rock. Although saprolites are classified as soils, they still contain the relict structure of the parent rock and some core stone of the parent rock. About 75 percent of the Zone IIA saprolites are classified as coarse grained (sands, silty sands), while the remainder are fine grained (clayey sands, sandy and clayey silts, and clays). The majority of the saprolites obtained from the borings in the slope area are dense silty sands.

Design Criteria and Analyses

SSAR Section 2.5.5.2 presents the design criteria for the slope, as well as an analysis of the static and dynamic (seismic) stability analysis. The design criteria used for the slope include the following minimum FSs:

- end of construction—FS=1.4
- long-term static (nonseismic)—FS=1.5
- long-term seismic—FS=1.1

The applicant inspected the slope during the ESP site investigation and found no signs of distress. In addition, a comparison of recent and old photographs of the site shows that the condition of the slope is unchanged.

For the static and dynamic analyses of the slope, the applicant used the computer program SLOPE/W, which is a commercial software product that employs limit equilibrium theory to compute the FS of earth and rock slopes. For the static analysis, the SLOPE/W program used the Bishop method of slices. The applicant assumed that the saprolite is predominantly coarse grained, with a unit weight of 125 pcf, an angle of internal friction (ϕ') of 30 degrees, and an effective cohesion (c') of 0.25 ksf. The resulting FS for the static analysis is 1.75, which is above the minimum FS of 1.5 for long-term static stability.

For the seismic slope stability analysis, the applicant used the pseudostatic approach, which assumes that the horizontal and vertical seismic forces act on the slope in a static manner as a constant force. Since an actual seismic event would last only seconds, with the peak motions occurring for a small portion of the total duration, the applicant concluded that the pseudostatic approach is a conservative approach. For the high-frequency earthquake, the applicant used a peak horizontal acceleration of 0.65g, which is the average peak acceleration in the top 55 ft of unimproved soil (see SSAR Table 2.5-46). Similarly, the applicant used a vertical peak acceleration of 0.32g. The applicant stated that the resulting FS is significantly less than 1.1, which is the minimum FS required for seismic slope stability. For the low-frequency earthquake, the applicant used a peak horizontal acceleration of 0.26g, which is the average peak acceleration in the top 55 ft, and a vertical acceleration of 0.13g. The computed FS for this case is slightly greater than 1.1.

As an alternative to applying the peak acceleration values for the pseudostatic analysis, the applicant chose to use horizontal accelerations of 0.15g and 0.10g and a vertical acceleration of zero. The applicant provided the following argument to support these acceleration values:

> Seed (Reference 186), in the 19th Rankine Lecture, addressed the over-conservatism intrinsic in the pseudo-static analysis. He looked at the more rational approach proposed by Newmark (Reference 187), where the effective acceleration time-history is integrated to determine velocities and displacements of the slope. He also examined dams in California that had been subjected to seismic forces, including several dams that survived the 1906 San Francisco earthquake. Based on his studies, he concluded that for embankments that consist of materials that do not tend to build up large pore pressures or lose significant percentages of their shear strength during seismic shaking, seismic coefficients of only 0.15g are adequate to ensure acceptable embankment performance for earthquakes up to Magnitude M=8.25 with peak ground accelerations of 0.75g. For earthquakes in the range of M=6.5, Seed recommends a horizontal seismic coefficient of only 0.1g with a vertical seismic coefficient of zero.

Since the fabric and interlocking angular grain structure of the Zone IIA saprolite have a low susceptibility to pore pressure buildup and liquefaction, the applicant concluded that it would not lose a significant portion of its shear strength during shaking. In addition, since the controlling earthquake magnitudes for the ESP site are 5.4 and 7.2, the applicant concluded that using the acceleration values recommended by Seed was justified. Using horizontal accelerations of 0.10g and 0.15g with a vertical acceleration of zero, the computed FSs are greater than 1.1, which is higher than the minimum FS for seismic slope stability. In summary, the applicant stated, "the Seed reductions are considered reasonable and valid, and the slope is considered to have an adequate factor of safety against failure during the ESP seismic event."

In RAI 2.5.5-1, the staff asked the applicant to provide its basis for concluding that the existing slope has a low susceptibility to liquefaction and, therefore, concluding that a horizontal acceleration of 0.1g is suitable for the slope stability analysis. In its response, the applicant stated that it revised its previous liquefaction analysis because it is now basing the SSE on the RG 1.165 approach. The applicant's revised liquefaction analysis (see SSAR Section 2.5.4.8) shows more widespread liquefaction within the Zone IIA saprolitic soils. However, since this analysis does not take into account the age, fabric, structure, and mineralogy of the saprolite, the applicant maintained that any liquefaction would not be widespread. The applicant also defended its use of 0.10g and 0.15g as the peak accelerations for the pseudostatic slope stability analysis. The applicant cited the research of Seed (Ref. 186, SSAR Section 2.5), who concluded that, if embankments do not liquefy or lose a significant amount of strength during a seismic event, they would displace at the crest but typically not fail in the conventional sense. The applicant stated that the design high-frequency earthquake has relatively low energy (magnitude 5.4), and therefore an acceleration of 0.10g is adequate. For the low-frequency earthquake, the applicant used a value of 0.15g for the peak acceleration. The pseudostatic slope stability analyses run with 0.1g and 0.15g both give FS values greater than 1.1.

The applicant also used the pseudostatic approach recommended by Kramer (Ref. 188, SSAR Section 2.5), which uses half of the peak acceleration value rather than a set peak value based on magnitude. Using Kramer's method, for the high-frequency earthquake, the applicant used a horizontal peak acceleration value of 0.325g and a vertical peak acceleration of 0.1625g. For the low-frequency earthquake, the applicant used a horizontal peak acceleration of 0.13g and a vertical peak acceleration of 0.065g. With these peak acceleration values, the applicant found that the FS is just below 1.0 for the high-frequency ground motion and greater than 1.1 for the low-frequency ground motion. Since the FS is below 1.0 using Kramer's method, the applicant stated that it could not rule of the possibility of some liquefaction in the slope area.

Boring Logs

The applicant drilled two sample borings on or close to the existing 2h:1v slope to the north of the SWR. Figures 2.5-71 and 2.5-72 in the SSAR reproduce the logs of the two borings.

Compacted Fill

SSAR Section 2.5.5.4 states that the existing 2h:1v slope is a cut slope and does not contain fill materials in any significant quantity.

Proposed New Slope

SSAR Section 2.5.5.5 states that a new slope may be excavated to the west of the SWR to accommodate UHSs for the new units. The new slope would be approximately the same height and would have the same 2h:1v slope as the existing slope. In addition, this proposed new slope would comprise similar materials as the existing slope. Therefore, the applicant concluded that the analytical conclusions for the existing slope would apply to the new slope; the new slope would be stable under seismic and long-term static conditions.

Conclusions

In SSAR Section 2.5.5.6, the applicant stated that, based on the possibility of some liquefaction in the slope area (existing slope), as well as the marginal results that it obtained using Kramer's method (Ref. 188, SSAR Section 2.5), it would take measures to ensure the safety of the slope and the structures that may be located close to the bottom of the slope. The applicant stated that these measures could include reducing slope steepness, removing and replacing materials that could lose significant strength during the design earthquake, and ground improvement measures such as soil nailing, moving structures further from the toe of the slope, and/or providing walls/barriers to protect those structures.

2.5.5.2 Regulatory Evaluation

SSAR Section 2.5.5 presents information on the stability of permanent slopes at the ESP site. The applicant stated in SSAR Section 1.8 that it developed the information regarding slope stability in accordance with the guidance presented in Section 2.5.5 of RS-002 and RG 1.70 and that the information is intended to satisfy the requirements of 10 CFR 100.23.

In its review of the application, the staff considered the regulatory requirements in 10 CFR 100.23, which states that the applicant for an ESP must describe the geologic and seismic conditions of the proposed site necessary to determine site suitability. Section 2.5.5 of RS-002 provides specific guidance concerning the evaluation of information characterizing the stability of slopes under SSE conditions.

2.5.5.3 Technical Evaluation

The staff's review of SSAR Section 2.5.5 focused on the applicant's analysis of the stability of an existing slope adjacent to the ESP site, the failure of which might impact future structures located close to the slope. The staff reviewed the applicant's description of the existing slope characteristics, design criteria and analyses, and proposed new slope and design modifications.

2.5.5.3.1 Slope Stability Analysis and Design Criteria

The staff focused its review of SSAR Sections 2.5.5.1 through 2.5.5.6 on the adequacy of the applicant's slope stability analysis of an existing slope adjacent to the ESP site. In addition, the staff reviewed the applicant's summary of the slope subsurface conditions, as well as its proposed new slope and potential design modifications to ensure the safety of the slope and of the structures located close to the bottom of the slope.

To perform the slope stability analysis, the applicant used three different pseudostatic approaches. For the first approach, the applicant used average peak vertical and horizontal acceleration values (0.32g and 0.65g), which resulted in FS less than 1.1. For the second approach, the applicant used the approach recommended by Seed (Ref. 186, SSAR Section 2.5), which recommends peak acceleration values based on the magnitude of the earthquake. Using the Seed approach, the applicant originally used peak vertical and horizontal acceleration values of 0.10g, in accordance with the magnitudes for the controlling earthquakes. With these lower peak accelerations, the resulting FS were greater than 1.1, which is the minimum FS acceptable for seismic slope stability. In RAI 2.5.5-1, the staff asked the applicant to provide its basis for concluding that a horizontal acceleration of 0.1g is suitable for the slope stability analysis. In response to RAI 2.5.5-1, the applicant stated that it revised the peak horizontal acceleration value to 0.15g, since the controlling earthquake using the RG 1.165 approach has a magnitude of 7.2. The pseudostatic slope stability analyses run with 0.10g and 0.15g both give FS values greater than 1.1. For the third pseudostatic approach, the applicant used the peak acceleration values recommended by Kramer (Ref. 188, SSAR Section 2.5), which are half of the average peak acceleration values (0.16g and 0.33g). Using these values the FS is below 1.0 for the high frequency controlling earthquake, implying the possibility of some liquefaction in the slope area.

The applicant concluded its response to RAI 2.5.5-1 by stating, "in recognition of the high near-surface accelerations and the results of the liquefaction analysis, the SSAR will be revised to indicate measures that would be taken to ensure the safety of the slope and of the structures that may be located close to the bottom of the slope." The staff concurs with this decision, since two of the three pseudostatic liquefaction analysis approaches result in FS less than 1.1. The staff concludes that, for the purposes of the ESP application, the pseudostatic analyses used by the applicant are adequate to analyze the stability of the existing slope. However, because the Zone IIA saprolites are susceptible to liquefaction, and because the existing slope could change, depending on final plant design and layout, the staff concludes that the COL or CP applicant should conduct a more detailed dynamic analysis of the stability of the existing slope and any new slopes resulting from plant construction using the SSE ground motion. This is **COL Action Item 2.5-10.**

2.5.5.4 Conclusions

Based on its review of SSAR Section 2.5.5 and the applicant's response to RAI 2.5.5-1, described above, the staff concludes that the applicant sufficiently analyzed the stability of the existing slope for the purposes of the ESP application. Because of the susceptibility of the Zone IIA saprolites to liquefaction, the staff concludes that the COL or CP applicant should conduct a more detailed dynamic analysis of the stability of the existing slope and any new slopes using the SSE ground motion. This is **COL Action Item 2.5-10.** A more extensive dynamic analysis would be appropriate at the COL or CP stage, since the applicant will have determined the locations of safety-related structures relative to the existing or new slopes. In addition, the COL or CP applicant should provide plot plans and cross-sections/profiles of all of the safety-related slopes and should specify the measures that it will take to ensure the safety of the slopes and any structures located adjacent to the slopes. This is **COL Action Item 2.5-11.**

2.5.6 Embankments and Dams

2.5.6.1 Technical Information in the Application

In SSAR Section 2.5.6, the applicant stated that, since Lake Anna would only be used for normal (i.e., non-safety-related) plant cooling of the new units, it did not reanalyze the North Anna Dam as part of the ESP application. According to the applicant, the North Anna Dam was designed and constructed to meet the requirements for a seismic Category I structure in support of the existing NAPS units.

2.5.6.2 Regulatory Evaluation

SSAR Section 2.5.6 states that the applicant did not reanalyze the North Anna Dam since Lake Anna would only be used for normal plant cooling of the new units. As such, the applicant did not list any regulatory guidance or cite any regulations as applicable to SSAR Section 2.5.6.

Section 2.5.6 of RG 1.70 describes the necessary information and analysis related to the investigation, engineering design, proposed construction, and performance of all embankments used for plant flood protection or for impounding cooling water. Sections 2.4.4 and 2.5.5 in RS-002 provide similar information and guidance.

2.5.6.3 Technical Evaluation

Section 2.4.4 of this SER provides the staff's evaluation of potential dam failures; Section 2.5.5 of this SER provides its evaluation of slope stability.

2.5.6.4 Conclusions

Sections 2.4.4 and 2.5.5 of this SER present the staff's conclusions regarding dam failures and slope stability, respectively.